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Analysis of Uncertainty in the Development of Integrated Solutions

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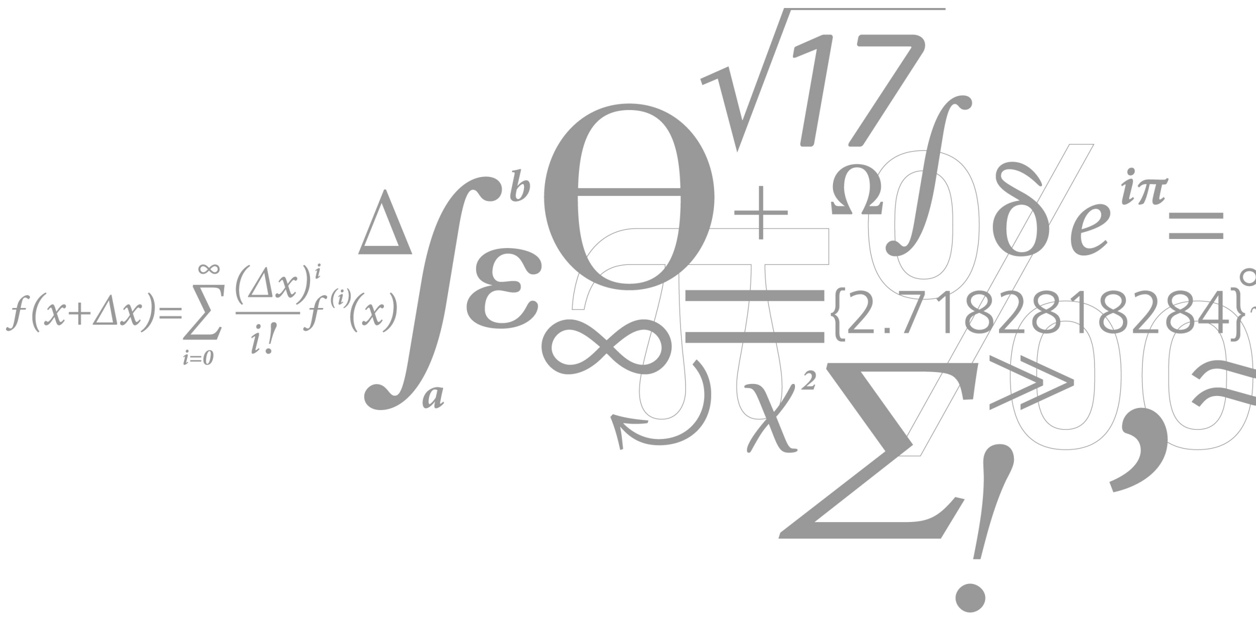

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DTU Management Engineering
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Innovation distinguishes between a leader and a follower.

- Steve Jobs

Note of Thanks

We would like to thank all participating companies for the possibility to conduct this benchmark on one of the current development cases. In particular we are thankful for the openness and curiosity brought forward by each company for the research topic of uncertainty management in the development of integrated solutions. This was strongly reflected in the extend of access to interviewees and data as well as openness to respond to subsequent inquiries.

We hope that each company finds the findings and carefully tailored recommendations inspiring and helpful. Feedback and interest in further research activities are very welcome. We wish all the best for the continuing development or execution of the integrated solution.

Executive Summary

The aim of this report is to provide insights into the uncertainty faced by manufacturers when developing integrated solutions. Integrated solutions are compound offerings comprising of a physical artefact (the product) and supporting engineering services. An example of integrated solutions is the Rolls Royce concept "Power by the Hour", charging the customer per hour of engine usage, not for the acquisition and maintenance of the engine itself. To provide these insights, this report describes the results of a benchmark study undertaken in the Nordic manufacturing industry. Six development cases of integrated solutions are compared and contrasted regarding the uncertainty encountered within five uncertainty types: Technical, environmental, resource, relational and organizational uncertainty. Moreover the six benchmark cases are analyzed regarding the criticality and latency of the uncertainty, as well as the uncertainty management practices applied. The benchmark study showed strong similarities as all uncertainty types were equally present:

- Technical uncertainty was encountered in modelling and forecasting of the machine performance, as well as the commercial scoping of the integrated solution.

- Environmental uncertainty was mostly characterized though uncertainty around country specific legal settings, challenges around the readiness of the customer for the offering, and the identification of the monetary value for the customer.

- Resource uncertainty centered strongly around human resources. Specifically the teams experienced uncertainty about the lack of project staffing, the availability of specialized skills (e.g. contracting, statistics), and the availability of staff to execute the integrated solution in the operational phase.

- Relational uncertainty emerged in the context of contracting through the identification of suitable terms and conditions for the integrated solution as well as the extent of risk included in the contract. Moreover, some companies engaged in co-creation processes and experienced relational uncertainty with the collaboration partners around hidden agendas, as well as quality and timing of the agree delivery

- Organizational uncertainty emerged in the adaptation of the development process to the characteristics of the integrated solutions, the shift in culture towards appreciating the value of service, risk averseness of the organizations, the organizational change, and the impact of the integrated solution on the company's business model.

Successful management strategies for the uncertainty emerging during the development of integrated solutions comprised mainly of the application of agile management practices, a high focus on stakeholder management, the application of a pre-pilot before the actual development project, and a high percentage of employee staffing on the project (80% of their time or more). Moreover, the development of internal capabilities in the field of statistics, modelling and forecasting of machine performance and contracting have proven highly beneficial. Lastly, fast feedback iterations with the customer or even co-creation had strong impact on the project success through the assurance of the customer's value.

Concluding, all companies experienced all five uncertainty types. Depending on the type of offering developed they were present to a varying degree. Yet, the organizational uncertainty type was most present in each case.

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1 Introduction

The quest of differentiation and competitiveness lead to the new era of engineering services. Increasingly, customers demand more added services such as equipment uptime and functionality over the artefact alone (Vasantha et al., 2012). The transition of manufacturers towards generating revenue from services is known as "servitization" (Baines and Lightfoot, 2013). The resulting offerings developed from the manufacturers are compound solutions comprising of the physical artefact (the product) and supporting services (Mont, 2002). These novel offerings are known in the literature i.a. as engineering services or integrated solutions (Kowalkowski et al., 2017). A prominent example of these integrated solutions is the offering “TrueChoice Flight Hour” from GE Aviation. This concept transfers risk from the customer to GE Aviation, reducing financial and operational uncertainty and can involve everything from time on wing and cost per shop visit to long-term cost of ownership, short-term cash flow risk or lease return condition risk (GE Aviation, 2017).

Transforming an organization from manufacturing and selling products to providing solutions creates various challenges for their internal processes but also their immediate network of suppliers, partners and customers. Resulting challenges are i.a. the adaptation of existing processes, shift in culture, fit with the core competences and lacking capabilities for the multidisciplinary development (Wolfenstetter et al., 2015). This has led to organizations not achieving all of the potential performance benefits of these new business models (Kindström and Kowalkowski, 2014). These potential benefits include differentiation, risk reduction through stable revenue streams, novel revenue streams or improved quality of customer relationship (Raddats et al., 2016). Yet many providers fail to achieve these and often find themselves with poor financial results or even bankruptcy.

Specifically the development of integrated solutions remains a core challenge. This requires a shift from a product-oriented to a function-oriented business perspective. Often they try to develop these solutions with their existing traditional development process for physical products (Beuren et al., 2013). Function-oriented business processes are complex and uncertain by nature. The novelty of the solutions for many manufacturing companies means that they lack and understanding and the relevant experience in developing them including the underlying internal processes and external partners. In academic terms, they face high levels of uncertainty when developing these solutions.

Purpose

The aim of this report is to provide insights into the uncertainty faced by manufacturers when developing integrated solutions. To provide these insights, this report describes the results of a benchmark study undertaken in the Nordic manufacturing industry. Six development cases of integrated solutions are compared and contrasted regarding the uncertainty encountered, the criticality and latency of the uncertainty, and the uncertainty management practices applied.

The report is structured into six main chapters. Chapter one introduces the report and its purpose. Chapter two gives a general overview of the theoretical background of the study. Chapter three describes the methodology applied in the benchmark. Chapter four describes the overall findings in the benchmark. Chapter five completes the report by giving suggestions based on the overall findings and insights from literature, and ends with a conclusion of the benchmark.

2 Theoretical Grounding

This chapter offers a brief overview of the theoretical setting of integrated solutions and uncertainty management in their development. It initiates with the definition of uncertainty and its relevance in solution development. Subsequently the chapter elaborates five relevant uncertainty types. It concludes with a short summary and a description of a potential of assessment criteria applied further in the benchmark.

2.1 Integrated Solutions and their Categorization

Integrated solutions are compound offerings comprising of the physical artefact (the product) and supporting services (Mont, 2002). On the transition towards servitization of companies different categorizations of these integrated solutions can be distinguished. These describe the path from still very product-related services, generating value mostly from the product content, towards highly service-oriented offerings, generating value mostly from the service content. One of the most commonly know categorizations in literature has been defined by Tukker (2004) and is adapted in this context. It distinguishes product-, use- and result-oriented solutions and gradually describes an organizational transition towards service provision.

Definition

Integrated solutions are compound offerings comprising of the physical artefact (the product) and supporting services. They may be distinguished into product-oriented, use-oriented and result-oriented integrated solutions.

In product-oriented solutions the business model is still mainly centered around the sales of the product with some extra services added. These could be product related services such as maintenance or supply of consumables as well as consultancy services around the product.

In use-oriented solutions the traditional product still plays a role, yet the service is not geared towards exclusively selling the product. The product may even stay in the ownership of the provider and made available in a different form. These service may comprise of product leasing, renting or sharing where the user pays for the use of the product.

Finally, result-oriented solutions describe concepts where the client and the provider agree on the result or outcome. In principle there is no pre-determined product involved (yet in practice it often bases on the core products of the companies). These concepts describe activity management, pay per service unit or agreements on functional results. A summary of the three concepts of integrated solutions can be seen in figure 1.

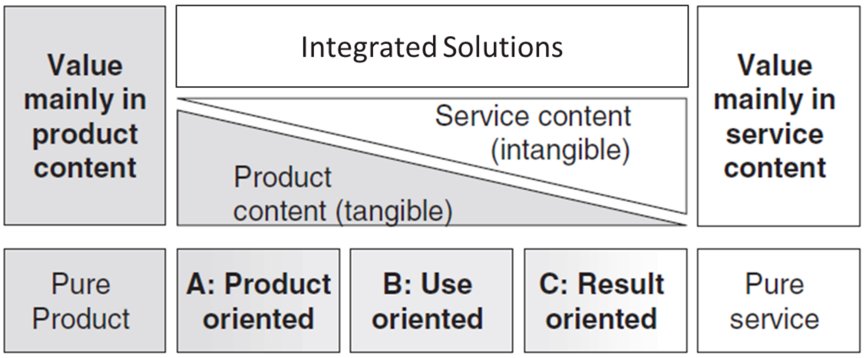

Figure 1: Categorization of integrated solutions adapted from Tukker (Tukker, 2004)

2.2 The Concept of Uncertainty

For the present research uncertainty is defined as lack of knowledge. This may arise from not known, not definite or not reliable information (Kreye, 2017*a*). This lack of knowledge leads to an unpredictability of a core characteristic and thus the outcome is simply not known (Knight, 1921). The definition implies a dual nature of uncertainty. As such uncertainty can have both a negative or a positive impact on the project outcome (Perminova et al., 2008). It may threaten the outcome of the project or enhance it through e.g. increased/decreased costs, longer/shorter lead time, lower/higher quality, higher/lower risk profile or less/more resources.

Definition

Uncertainty is defined as lack of knowledge which may arise from not known, not definite or not reliable information.

In the context of solutions development the concept of uncertainty requires special attention. The development of integrated solutions differs strongly from traditional product development because it introduces new "soft" variables through the service component (Crawford and Pollack, 2004). These new variables redefine the existing uncertainty for traditional product development like technical uncertainty, environmental uncertainty, organizational uncertainty and resource uncertainty (O'Connor and Rice, 2013).

One example is the redefinition of the pricing scheme. Traditionally in product development a cost-plus approach, summing up the component costs and adding a margin, was dominant in the manufacturing industry. This approach calls for a complete redefinition once the service aspect is taken into account. Uncertainty of forecasting the amount of maintenance and ad hoc failure challenges the industry. Moreover the value based pricing, defining the price according to the value for the customer, implies uncertainty about value estimation.

In general the solution development process is characterized through high operational complexity of developing products and services in parallel (Zhang and Banerji, 2017), the high degree of stakeholder involvement (Martinez et al., 2010) and distinct requirements through the long life cycles of integrated solutions (Zhang and Banerji, 2017). Because of these varied sources of uncertainty, the uncertainty types existing for product development need to be differentiated for the context of solution development.

2.3 Five Uncertainty Types in the Development of Integrated Solutions

Based on an exploratory literature analysis a conceptual framework of five uncertainty types occurring in solution development was developed. The literature analyzed comprised the literature streams of servitization, project management and (radical) innovation management. The analysis centered around identifying relevant uncertainty occurring in solution development and grouping them into major uncertainty types. Moreover, suitable uncertainty management practices were identified from the literature analysis.

The five uncertainty types are distinguished as organizational, relational, resource, environmental and technical uncertainty. The framework is the basis for the benchmark of uncertainty management. All participating companies will be compared and contrasted with each other based on these five categories. Moreover, the companies will be compared to the uncertainty identified in the literature analysis. Figure 2 shows a general overview of the categories. A detailed description will follow in the next chapter.

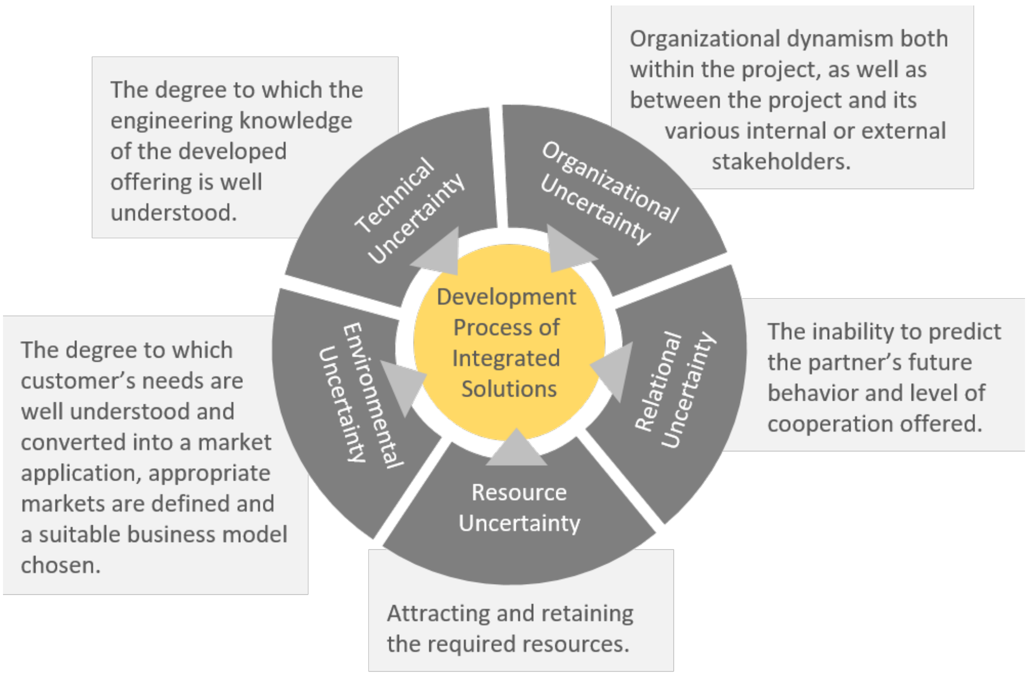

Figure 2: Uncertainty typology for development of integrated solutions (Ramírez Hernández et al., 2018)

2.3.1 Technical Uncertainty

Technical uncertainty describes the degree to which the engineering knowledge of the developed offering is well understood (O'Connor and Rice, 2013) as well as technological challenges caused by the long life cycle orientation of the integrated solutions (Isaksson et al., 2009). It mainly revolves around techno-paradigmatic and complexity-related problems, in which high complexity and continued change call for high flexibility (Melander and Tell, 2014).

In integrated solutions development, technical uncertainty may relate to three aspects: the product, the service and their systemic integration. First, technical uncertainty regarding the product component is related to the degree to which the foundational scientific knowledge is well understood and applied in form of a cost-efficient and manufacturable product (O'Connor and Rice, 2013). Moreover, it describes the challenge of integrating several components from multiple engineering disciplines e.g. IT, electrical engineering, mechanical engineering, mechatronic engineering, chemical engineering, metallurgical engineering (Wolfenstetter et al., 2015). Second, technical uncertainty regarding the service component can relate to high variability of the service definition due to its customization (Nordin et al., 2011) and the uncertainty in forecasting of timing and scale of the service over a long life cycle span (Isaksson et al., 2009). Third, the technical uncertainty related to the systemic integration between product and service may be particularly challenging. On the one hand, managing all interfaces of the solution design in the context of their integration can create high complexity due to high complicatedness (Benedettini and Neely, 2012). Technical uncertainty here arises through the task of complexity management. Specifically, it arises in foreseeing all possible combinations of product and service modules, keeping the mutual influences between them in mind, and the subsequent challenge to design all interfaces to be operational for all combinations predicted beforehand (Isaksson et al., 2009).

Definition

The degree to which the engineering knowledge of the developed offering is well understood.

2.3.2 Environmental Uncertainty

Environmental uncertainty refers to lack of knowledge about the external environment (Milliken, 1987). It includes the market uncertainty described by O'Connor and Rice (2013) in the context of radical innovation. The market uncertainty refers to the degree to which customer's needs are well understood and converted into a market application, appropriate markets are defined and a suitable business model chosen (O'Connor and Rice, 2013).

Predicting these external factors and their effect on the integrated solutions can pose a challenge in solution development. The lack of understanding customer needs and the intended market segment is one of the core challenges of solution development (Spath and Demuß, 2001). Once they are understood the subsequent challenge lies in defining this new type of value proposition and the surrounding business model dues to e.g. lack of readiness from the customers for this type of advanced offering (Lay, 2014). Furthermore, larger macro-economical developments can represent sources of environmental uncertainty. These developments may comprise of changes in legal requirements and regulations or changes in the financial market (Kreye, 2017*a*). Moreover, technological developments may represent a source of environmental uncertainty (Reim et al., 2016) threatening e.g. technological obsolescence (Wolfenstetter et al., 2015).

Definition

The degree to which customer's needs are well understood and converted into a market application, appropriate markets are defined and a suitable business model chosen.

2.3.3 Resource Uncertainty

Resource uncertainty refers to challenges arising from attracting and retaining the required resources (O'Connor and Rice, 2013). Resources may be defined as both tangible and intangible entities (Kreye et al., 2015). They may consist of competences, critical information, financial resources as well as other resources required.

The high degree of complexity of integrated solutions (Zhang and Banerji, 2017) and tailoring to the customer's needs typically requires high amounts (Benedettini and Neely, 2012) or very specific resources (Kastalli and Van Looy, 2013). These specific resources may refer to technical engineering and managerial capabilities (Wolfenstetter et al., 2015) or a certain seniority required for a particular activity (Atkinson et al., 2006). Due to these demanding requirements companies experience uncertainty about the internal or external existence or availability of these specific resources (Wolfenstetter et al., 2015). Moreover, solution development often implies co-creation, which involves the customer as a crucial operant resource. Here the customer represents a source of resource uncertainty as the project depends to a high degree on his input (Benedettini and Neely, 2012). A last example of resource uncertainty may originate from the major change in cash flow. The operation of integrated solutions often requires major initial investments and implies a delayed cash flow. Resource uncertainty arises from the need to convince external financial partners of the concept of integrated solutions to bridge the initial period (Barquet et al., 2013).

Definition

Attracting and retaining the required resources.

2.3.4 Relational Uncertainty

Relational uncertainty refers to the inability to predict the partner's future behavior and level of cooperation offered (Kreye, 2017*b*). In solution development the relational uncertainty is central because of the high degree of stakeholder involvement in the development process as well as the large size of the internal and external stakeholder network (Baines et al., 2007).

Relational uncertainty may arise in solution development if new business models are co-created with customer or supplier (Kreye et al., 2015). Because the process of co-creation in solution development requires more sophisticated relationships (Isaksson et al., 2009) than traditional product development, relational uncertainty is reflected in the willingness, availability and ability of the partners to collaborate (Atkinson et al., 2006). These more sophisticated relationships demand i.a. increased information exchange, joint realization of innovations and especially, fast addressment of occurring disagreements and problems. Accordingly, relational uncertainty may originate from e.g. lack of trust, low commitment, deficient information sharing as well as a disjoint approach to problem solving (Kreye et al., 2015) resulting in a partner's inability to perceive or deliver the service (Kreye, 2017*b*), i.e. weak inter-personal or inter-organizational relationships (Kreye et al., 2015). Another example of relational uncertainty in the context of solution development are challenges in service contracting. Since integrated solutions build upon a long-term provider-customer relationship contracting capabilities of both parties are crucial (Kreye, 2017*b*). Especially the definition of the split of i.a. costs, risk and intellectual property (Isaksson et al., 2009) between the collaboration partners can create challenges.

Definition

The inability to predict the partner's future behavior and level of cooperation offered.

2.3.5 Organizational Uncertainty

Organizational uncertainty is defined as organizational dynamism both within the project, as well as between the project and its various internal or external stakeholders (O'Connor and Rice, 2013). It is reflected in terms of the organization's strategy, priorities and available resources (Kreye, 2016).

The challenges for integrated solutions here may be similar to product development projects where stakeholder interests can vary, project planning and execution can be challenging, or functional interfaces within the organization can change (O'Connor and Rice, 2013). Yet the stakeholder network in solution development typically is larger and more drivers for solution development (Martinez et al., 2010). An example of organizational uncertainty here is the goal definition. Potential hidden agendas as well as different stakeholder interpretation of qualitative and intangible results can inhibit the clear definition of the overall goal (Atkinson et al., 2006). Besides the challenge of stakeholder management additional organizational uncertainty may arise from the mix of cultures within an organization. Especially companies with a traditional product development mindset require a cultural change towards service provision. This shift may be challenging, for where the traditional focus was laid on efficiency and economies of scale, it now moves towards customization and flexibility in a service provision (Gebauer et al., 2005). In this setting, uncertainty arises because competence profiles, functions and processes need to be redefined and external partnerships reshaped according to the new requirements (Wolfenstetter et al., 2015). A last example for a cause of organizational uncertainty is the pricing of the integrated solutions at the bidding stage (Kreye et al., 2014). Root causes for uncertainty of pricing are i.a. connected to vagueness in cost-estimations (Kreye et al., 2014) or estimating the value for the customer in the context of performance based pricing (Barquet et al., 2013).

Definition

Organizational dynamism both within the project, as well as between the project and its various internal or external stakeholders.

2.3.6 Knock-on effects

A knock-on effect is an uncertainty caused by another uncertainty (Kreye, 2017*a*). Often these knock-on effects occur with uncertainty from different uncertainty types, i.e. uncertainty from one uncertainty type causing additional uncertainty in another uncertainty type. These knock-on effects are of high relevance as they emphasize the systemic appearance of uncertainty. A prominent example to illustrate a knock-on effect is the impact of environmental uncertainty on the organizational uncertainty. Here the unpredictable state of the environment (environmental uncertainty type) can cause uncertainty within the organization regarding suitable organizational responses (organizational uncertainty type) (Kreye, 2017*a*).

Definition

A knock-on effect is an uncertainty occurring caused by another uncertainty.

2.4 Summary

Uncertainty is defined as lack of knowledge in the context of the present research. This may arise from not known, not definite or not reliable information (Kreye, 2017*a*). As the solution development process shows distinct characteristics when comparing it e.g. to traditional product development, the uncertainty types have to be redefined. In the course of the research project five major uncertainty types have been identified.

3 Method

This chapter describes the methodological approach of choosing, collecting and analyzing the cases of the benchmark study.

3.1 Benchmark Cases

A benchmark study of six cases was done in the Nordic manufacturing industry. Even though the companies operated within the manufacturing industry different sectors were chosen to keep the findings independent from individual market influences. Besides the criteria to be part of the manufacturing industry, all companies were large manufacturers (no SMEs). As they were leading players within their field, they had the (financial and organizational) ability to explore the front end of service development.

Lastly, a general categorization of integrated solutions was used to select the cases to be analyzed at each company. Based on the categorization of integrated solutions provided by Tukker (Tukker, 2004) two cases for each category were selected for the benchmark. The figure 3 summarizes the case selection from the benchmark.

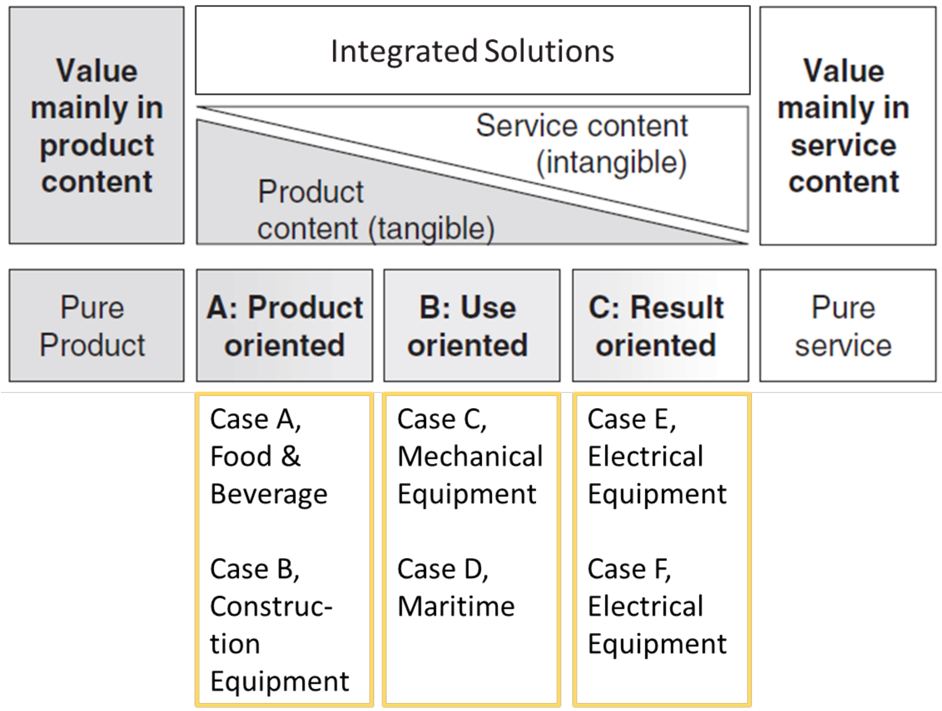

Figure 3: Case selection in the benchmark

3.2 Collection and Analysis

The case study comprised of semi structured interviews analyzing one recently terminated or on-going, complex development project of an integrated solution at each company. Multiple people involved in the development project were interviewed to get insights into their experience and evaluation of the situation. These people were part of development teams and included i.a. project managers, developing engineers, accountants, product managers, project owner and/or production planners. Per case company approx. 8-15 interviews of 1 hour each were conducted. Overall the benchmark comprised of 64 interviews. The questionnaire of the semi-structured interviews can be seen in the Appendix I.

Furthermore, project documentation and other supportive company specific material were analyzed to gain a completing overview of the development process of integrated solutions. This supportive material comprised of i.a. meeting minutes, project plan, change log, steering committee meeting presentations and gate presentations. In total 166 supporting documents were analyzed in the context of this benchmark. The aim was to give a rich picture of solution development to understand the uncertainty faced in the process, their causes, and how they are managed by the core development team.

After the data collection all the data was coded according to the theoretical framing presented in chapter two. This led to a detailed map of uncertainty in the development process of each case company enabling a thorough within-case analysis. Subsequently, a cross-case analysis was conducted to obtain the findings of the benchmark study. Best practices and patterns for the solution development were identified and compared and contrasted against insights from literature. Finally, recommendations based on the best practices and literature were derived.

4 Benchmark

This section presents the overall results of the benchmark based on the cross-case analysis of the six cases. First the section presents a short description of the cases and the participating companies. Then an overall summary of the benchmark result is presented. Subsequently detailed information on the individual uncertainty within each uncertainty type is presented and illustrated through examples from the cases. The description of each uncertainty type also contains two diagrams shortly summarizing the uncertainty occurred and classifies them according to general project uncertainty, and uncertainty specific for the development of integrated solutions. This section ends with a short summary.

4.1 Cases of the Benchmark

All cases were chosen from the Nordic manufacturing industry with headquarters within Europe. To avoid sector specific influences the manufacturers were chosen from different industry sectors. Although the cases varied in the type of integrated solution, none of the companies had yet explored the concept of keeping ownership of the product. Table 1 below summarizes a description of the company and the solution type of the six cases from the benchmark.

Company	**Description of the Integrated Solution**
Case company A Sector: Food & Beverage Equipment	Type of integrated solution: Product-oriented Description: Product-related service applied during the use-phase of the machine. The provider monitors and analyzes performance related data of the machine to give suggestions for the optimization of the production. The offering also includes the provision of maintenance and spare part supply.
Case company B Sector: Construction Equipment	Type of integrated solution: Product-oriented Description: Product-related service applied during the maintenance-phase of the machine. The provider monitors and analyzes the wear progression of the parts to give a forecast of their remaining life time. Additionally, the design of future parts is optimized in house for each individual customer to provide tailor made parts. The offering also comprises of the part supply.
Case company C Sector: Mechanical Equipment	Type of integrated solution: Use-oriented Description: Agreement between provider and client on a pay as you save contract. The provider offers an optimized and intelligent machine, and is responsible for the maintenance and monitoring of the machine performance (and thus resulting savings) during the production.

Company	Description of the Integrated Solution
Case company D Sector: Maritime Equipment	Type of integrated solution: Use-oriented Description: Long-term use-oriented proactive maintenance contract. The provider and the client agree on the maintenance and spare part needed for the long contracting period to increase the time between overhauls. Based on the contract the provider grants an extension of the product warranty. The client pays a regular fee for the use of the product and has unlimited access to the product.
Case company E Sector: Electrical Equipment	Type of integrated solution: Result-oriented Description: Agreement between provider and client on the provision of a functional result on a plant level. The functional result is provided per year. The provider is, in principle, completely free as to how to deliver the result.
Case company F Sector: Electrical Equipment	Type of integrated solution: Result-oriented Description: Agreement between provider and client on the provision of a functional result on a plant level. The functional result is provided per year. The provider is, in principle, completely free as to how to deliver the result.

Table 1: Summary of the benchmark cases

4.2 Overall Benchmark Results

The results show uncertainty which occurred commonly across two cases or more. Individual uncertainty which arose in addition to the commonly described uncertainty are not published in the context of the report to protect the companies' privacy and identity. However, most uncertainty perceived by the companies during the development of integrated solutions were commonly perceived uncertainty. The overall picture of the benchmark results show that the development of integrated solutions is non-trivial and characterized through high uncertainty. All uncertainty types were present in all cases - although to a varying degree. The summarizing overview in figure 4 expresses the uncertainty and its severity in a qualitative measurement:

- x - low impact,
- xx - medium impact,
- xxx - high impact.

This reflects that, although uncertainty was present across cases they varied in their intensity. Examples of these variations are given in each uncertainty description. The last row summarized the number of different uncertainty per case, the last column to the right reflects the frequency of the uncertainty across the cases.

Most commonly perceived technical uncertainty arose around modelling and forecasting the machine performance and the general scoping of the project. Also environmental uncertainty challenged all companies. Specifically, volatile market conditions, strong competition and the uncertainty around the customer's needs were particularly strong. Resource uncertainty occurred mostly around project staffing, as well as the attraction of resources needed for the actual execution of the integrated solution. Relational uncertainty was strongly perceived regarding the right terms and conditions in the contracting for the integrated solution, as well as the collaboration with (or dependency on) external partners. Lastly, organizational uncertainty represented the biggest obstacle to all cases. Especially the establishment of a supporting service culture, the impact of organizational change on the project, as well as the value-based pricing approach created challenges. In the following sections the encountered uncertainty is elaborated in more detail and illustrated with suitable examples from the benchmark cases.

Uncertainty	Case A	Case B	Case C	Case D	Case E	Case F	Total
Technical Uncertainty							
Handling large amounts of data		xxx	x			xx	3
Modelling and forecasting		xxx	xx	xx	xx	xx	5
Scoping	xx	x	x	x	xxx		5
Roll-out across the product portfolio	xx	xx	xx	x			4
Hard- and/or software issues	xxx	x		x			3
Environmental Uncertainty							
Volatile market conditions	x	xxx	x	xxx	xx	xx	6
Strong competition	x	xxx	xx	xx	xx	xx	6
Customers	x	xx	x	x	xx	xx	6
Country specific legal settings			xx	xx	xx	x	4
Changing legislations	xxx		x				2
Resource Uncertainty							
Data	x		x		xx	xx	4
Project staffing	x	xx	x	x	xx	xxx	6
Preparations for execution	xx	xxx	xxx	x		x	5
Relational Uncertainty							
Contracting	x	x	x	x	x	x	6
Collaboration partners	xxx		x	xx	x	xx	5
Organizational Uncertainty							
Risk averseness			xx		xxx	xx	3
Service culture	xxx	x	xxx	x	x	x	6
Service portfolio management	x				x	xx	3
Internal placement and alignment of the project			x	xxx	xxx	x	4
Slow internal processes	xx			x		xx	3
Organizational change	xxx	x	x		x	xxx	5
Internationality/Diversity of the company		xxx	x	xx		x	4
Language		xx			x		2
Adaptation of IT systems	x		xx				2
Pricing	x	x	x	xxx	x	x	6
Functions and processes for integrated solution execution	xx	x	x	xx		x	5
Development process				xx	xxx	xx	3
Total: 27 common uncertainties	19	17	22	19	18	21	

Figure 4: Overall results of the benchmark

4.3 Technical Uncertainty

Technical uncertainty refers to the degree to which the engineering knowledge of the developed offering is well understood. It occurred in form of handling of large amounts of data, modelling and forecasting, scoping, roll-out across the portfolio, as well as hard- and software issues.

4.3.1 Handling Large Amounts of Data

The amount of data needed for the solution development created high uncertainty. Specifically, uncertainty arose around understanding the type of data which needed to be processed, navigating these large data sets, and selecting an appropriate processing method regarding the specific characteristics of the data.

Uncertainty Specific for Integrated Solution Development

Handling Large Amounts of Data
Uncertainty arose around understanding the type of data which needed to be processed, navigating these large data sets, as well as the selecting an appropriate processing method regarding the specific characteristics of the data.

As an example, Case B was challenged through familiarizing itself with a completely new type of data set which it had not handled before. In particular, the team faced the challenge of modelling large point clouds within the existing software landscape. Here challenges arose around the comprehension of the actual information, the handling of this large data set, as well as the selection of appropriate modelling methods. Unlike Case B, the team of Case F was familiar with the type of data. Here uncertainty arose around handling of such large data sets. Moreover, the team was uncertain around the corresponding engineering knowledge to process it.

Examples from the Cases

Case B
Uncertainty through a novel and very large data set.
Case F
Uncertainty regarding the appropriate method to navigate the data set.

4.3.2 Modelling and Forecasting

Technical uncertainty in this context referred to the complexity and application of engineering knowledge around modelling and forecasting of the machine performance. This uncertainty occurred in two forms. First, uncertainty was perceived around the accuracy level achievable with the current methods applied. The output of the accuracy would determine the scoping of the offering and as such, its market-attractiveness. This uncertainty implied insecurity about the degree of the engineering knowledge applied to model and forecast the performance with the existing methods was well understood. Second, uncertainty was perceived around the potential existence of more suitable methods to improve the accuracy. As the companies were applying cutting edge engineering knowledge in new engineering disciplines, uncertainty arose about the suitability of existing tools and methods applied in-house for the modelling and forecasting required in the solution development.

Uncertainty Specific for Integrated Solution Development

Modelling and Forecasting
Uncertainty referring to the complexity and application of engineering knowledge around modelling and forecasting of the machine performance.

One illustrating example of this uncertainty was experienced by Case B. In the beginning of the project the team was unsure whether it was able to model and forecast the machine performance at all. Progressing further in the development the team then faced the challenge of dealing with many unpredictable variables in the modelling process and thus, the uncertainty about the possible accuracy of the outcome. In addition, the team reached the limit of the software available in-house. This led to uncertainty about the existence of a suitable software to enable the accuracy required, and the possibility to acquire.

Also Case F faced uncertainty around modelling and forecasting. In this case the team was particularly challenged to model and forecast the machine performance over a period of several years. Current modelling techniques applied in the company were not accurate enough yet due to limitations in the model, uncertain assumptions, or unreliable modelling parameters. Moreover, the engineering knowledge necessary had never been required before in the company as modelling and forecasting of this type had not been done before.

Examples from the Cases

Case B
Uncertainty about the fundamental possibility and accuracy of modelling and forecasting the machine performance.
Case F
Uncertainty around forecasting over long periods of time and the corresponding accuracy.

4.3.3 Scoping

Uncertainty around the scoping of the integrated solution arose from both, the technical and the commercial component of the solution. In most cases the teams were challenged to balance the technical capabilities of modelling and forecasting the machine performance, with the degree of coverage implied in the offering. Accordingly, uncertainty arose around the creation of an attractive offering while not exposing the company to unknown risk factors in long-term contracts.

Uncertainty Specific for Integrated Solution Development

Scoping
Uncertainty around the scoping of the integrated solution arose from both, the technical and the commercial component of the solution.

In Case C the scoping targeted specifically the commercial part of the offering and the underlying financial model. Uncertainty arose around the question of ownership: should the machine shift ownership during the operation of the integrated solution to the customer, or not? Moreover, the team was unsure whether to create an output-based or a savings-related financing scheme, and whether that scheme should comprise of a partially or fully variable fee. Lastly, the forecast of the machine performance based on data from an initial site audit. Here the team perceived uncertainty about the level of risk implied through basing the whole performance forecast on one initial performance measurement. An alternative would be to conduct several site audits in the course of the operational phase of the integrated solution.

Also Case E struggled with strong uncertainty around the scoping of the integrated solution. Here uncertainty around the scoping of the integrated solution arose from both, the technical and the commercial component of the solution. The overall uncertainty targeted the level of risk covered in the integrated solution, and therefore the level of risk exposure acceptable for the company. The team had to balance the technical possibilities of what the company was able to forecast, with the resulting commercial offering of risk coverage for the customer. This process was particularly challenging for the team because the underlying development process of the company only partially allowed the team to answer the question about the technical forecasting capabilities in the scoping phase. This implied the uncertainty of potential rework of the commercial offering once the technical development had ended, and the level of forecasting accuracy could have been determined. Resulting from the paradox caused by the development process the technical and commercial scoping of the offering was based on a high amount of assumptions. This created uncertainty in the team about the accuracy of the assumptions and thus the appropriateness of the level of risk covered in the integrated solution. This constituted a knock-on effect to the relational uncertainty regarding the contracting. Here the uncertainty was experienced about the type and amount of exclusions incorporated.

The uncertainty about the level of risk inclusion in the project scoping represented also a knock-on effect of the environmental uncertainty. As competition increased and the company's market intelligence had reflected the team that the competitors were equally experimenting with this type of risky integrated solution, uncertainty in the scoping phase also arose in terms of the competitiveness of the offering. The team had to balance the total risk exposure of the company and the ability to stay competitive with the amount of risk coverage.

Examples from the Cases

Case C
Uncertainty around the shift of ownership, the financial scheme and the frequency of performance measurement.
Case E
Uncertainty regarding the level of risk exposure covered in the offering.

4.3.4 Roll-out Across the Product Portfolio

Uncertainty around the roll-out of the developed integrated solution across the product portfolio arose due to differing features of the distinct products. These differing technical features constituted different data sets for the performance modelling and forecasting and created uncertainty about the applicability of existing engineering knowledge.

Uncertainty Specific for Integrated Solution Development

Roll-out Across the Product Portfolio
Uncertainty arose around the differing technical features of the machines. These constituted different data sets for the performance modelling and forecasting and created uncertainty about the applicability of existing engineering knowledge.

In Case B the size of the point cloud gained from the scan of the products differed highly from product to the next. This implied strong uncertainty for the development team in managing the large data sets and navigating the modelling and forecasting with the tools and methods existing in-house for differing types of machines. As a result, the modelling and forecasting called for a different software capable of processing these large point clouds in order to offer the integrated solution for more complex machines as well.

Case D faced the uncertainty about the portfolio roll-out due to constantly changing designs of the machines. The design department of the company continuously revised and optimized the machine design which led to a fleet of highly individual machines. This required highly individually tailored integrated solutions, specifically regarding the spare part provision and created uncertainty about the scope of supply.

Examples from the Cases

Case B
Uncertainty arising through differing features of the diverse products from the portfolio the service element needs to be adapted to.
Case D
Uncertainty due to constantly changing machine designs.

4.3.5 Hard- and/or Software Issues

Uncertainty arising from the product-part of the integrated solution was connected to the hard- and software of the offering. Specifically, this uncertainty describes challenges which arose through faulty or incomplete hard- or software, as well as their integration in the existing system landscape.

Uncertainty not Related to Integrated Solution Development

Hard- and/or Software Issues
Uncertainty emerged from the product-part of the integrated solution and was connected to the hard- and software of the offering.

One illustrative example of this uncertainty arose in Case A. Strong uncertainty was perceived around the cause of a faulty industrial PC, as well as changing and partially faulty functionalities after software updates. Moreover uncertainty arose around the complexity of defining software interfaces. Here the integration of the developed software within the existing software landscape was particularly challenging due to the high level of detail required.

Case C struggled with technical uncertainty arising from the hard- and software in a different context. Since many years the company had produced high quality machines with a long lifespan. Trying to offer an integrated solution based on a historical fleet challenged the development team through uncertainty around the serviceability of the installed base. Here the team faced high complexity as each product line with the historical models implied differing possibilities for integrating smart modules which were central for the provision of the integrated solution. In younger designs with modular design the integration was eased. However, the older generations of the machines required major redesigns. This also caused discussions in the team about the degree, to which the existing machines had to become smart, i.e. which would be the minimum level of intelligence the machine would need in order to offer the integrated solution.

Examples from the Cases

Case A
Uncertainty in the course of a long-lasting fault search and functional impacts after software updates.
Case C
Uncertainty about the applicability of the integrated solution to older, non-smart product-lines.

4.4 Environmental Uncertainty

Environmental uncertainty is defined as the degree to which customer's needs are well understood and converted into a market application, appropriate markets are defined and a suitable business model chosen. In this benchmark it occurred around volatile market conditions, strong competition, customers, country specific legal settings, as well as changing legislations.

4.4.1 Volatile Market Conditions

Commoditization of product and service offerings alongside with changes in legislation and price decrease resulted in high market volatility and a decrease in profit margins. In addition, increasing customer demands for more advanced product and service offerings in combination with a generally decreasing world economy threatened the companies. These conditions led to uncertainty about suitability of the company's operating model and product offerings. In all cases the market conditions paired with the customer demands and the competitive situation represented the motivation for the development of the integrated solutions analyzed in this benchmark.

Uncertainty not Related to Integrated Solution Development

Volatile Market Conditions
uncertainty about changes in the external environment and the suitability of the company's operating model and offerings.

Case D experienced the increased volatility of the maritime market. Here the market conditions and especially the international economy played an important role due to the high degree of mobility and globalization implied by the maritime industry. This global market uncertainty led to high variability in central elements of the integrated solution like spare part pricing, resource availability for service execution, or overall market demand. Accordingly, the team perceived high uncertainty in forecasting these elements for the long contracting period.

Similarly Case B operated under challenging conditions in the mature construction industry. The aftermath of the financial crisis constituted commoditization of products and services. Correspondingly, margins dropped and the company struggled to keep contact with the highly price sensible customers. Here the offer of integrated solutions represented a possibility to be physically present at the customers site again and rebuild a strong customer relationship.

Examples from the Cases

Case D
Uncertainty due to unstable spare part pricing, resource availability and market demand.
Case B
Uncertainty caused by aftermath of the financial crisis through dropping margins.

4.4.2 Strong Competition

All cases perceived environmental uncertainty through the unpredictability of the competitor's actions. In cases of lower environmental uncertainty the company experimented with new technology in the context of the integrated solution while building on a solid competitive position through the core business. In cases of medium environmental uncertainty companies perceived competitive activity regarding a highly similar competitive offering to the one, the companies were developing in-house. In cases of strong environmental uncertainty some competitors were already selling a similar version of the integrated solution and customers challenged the companies to catch up as fast as possible. In addition, high changes in the competitor landscape due to novel competitors challenged the cases.

Uncertainty not Related to Integrated Solution Development

Strong Competition
Uncertainty through the unpredictability of the competitor's actions.

In Case E the market conditions created a highly competitive environment with a changing competitor landscape. Competitors comprised of the already known set of competitors, of novel, small-scale players emerging locally in the markets close to the customer's sites, and larger novel player from adjacent industry sectors offering hybrid solutions. Moreover, some competitors of the case company also started to explore the field of the integrated solutions. Specifically, some customers reflected to have received offers from familiar major competitors of the case company. This created uncertainty about a potential competitive offering scoped in the same or similar way, about the development pipeline of the competitor, and about the time to market left for the case company to spearhead the market offering. Additional uncertainty arose around the risk implied by the offering. Here attention was paid to how far the case company was actually pushing the market and its competitors into an uncomfortable direction for both, the company and its competitors. This uncertainty regarded the trade-off between developing offerings to stay competitive and profitable, and driving the market in the direction of risk offerings none of the players would like to offer. Especially considering that once a high-risk integrated solution would be offered by one player, the other players would catch up soon, and the beforehand considered "risky offering" would become a commodity with pure competition based on the price.

Although in Case C no competitive activity was yet perceived by the company's market intelligence regarding the specific integrated solution, the company nonetheless struggled with the competitor landscape. Here the provision of the integrated solution would change the competitor landscape strongly and many, previously unknown players would become competitors. This called for a strong competitor analysis differing across the regions. In addition, through offering the integrated solution the company would become a competitor of some of it's distributors. Here a fine balance had to be found for keeping the distributors motivated to sell the existing base of product and service offerings, while still tentatively competing with the distributors through the integrated solution. This caused infringements between the existing portfolio of the product and service business, and the new offering.

Examples from the Cases

Case E
Uncertainty about strong known as well as novel, local competitors, and pushing the marked in an undesirable direction through the offering.
Case C
Uncertainty about the novel competitive landscape when offering the integrated solution.

4.4.3 Customers

Uncertainty around the customer represents one of the most classical environmental uncertainty. It describes the degree to which the customer's needs are well understood and converted into a market application, appropriate markets are defined and a suitable business model chosen. In the context of the benchmark it represented a highly critical uncertainty because all companies were in the transition towards servitization, i.e. the provision of integrated solutions. Although the companies were servitized to a varying degree, some rather product-oriented and others more functional-oriented, the developed offering was still of high radicality for their markets and characterized through high uncertainty. While all cases perceived strong uncertainty around the customers, the two examples describe highly illustrative the differences between uncertainty in the initial steps towards servitization versus advanced servitized players.

Uncertainty Specific for Integrated Solution Development

Customers
Uncertainty about the degree to which the customer's needs are well understood and converted into a market application, appropriate markets are defined and a suitable business model chosen.

In the market of Case A, players began only in recent years to explore the initial concept of servitization and as such the offerings were rather product-oriented. The company perceived strong uncertainty around the customer readiness for the offering. Specifically, the company was challenged through customers not understanding the need for services beyond the classical maintenance and spare part supply, let alone the provision of integrated solutions. This created strong uncertainty about the overall acceptance of the offering on the market. In addition to the challenges around the customer readiness, the company struggled to identify the customer requirements. Operating internationally with a broad base of customer segments, the development team faced to balance requirements from individual customers, or customer segments, with the development of a generalized offering which would still serve the individual requirements. Accordingly, the team struggled with the commercial identification of the core customer need. Derived from this struggle, the development team perceived uncertainty about the overall value of the offering for the customer. Specifically the identification of the value for the customer and how to measure it created uncertainty for the development team.

Besides the struggles about the customer readiness, the customer requirements, and the actual value of the offering for the customer, the team also faced uncertainty about access to the customer. Here access to the real-time data from the customer was central for the provision of the integrated solution. Uncertainty arose here through raised IT-security standards at the customer's sites. As a result the company faced e.g. increased firewall requirements and the need for obtaining additional IT-security certificates to meet the safety standard of the customers. In extreme cases the machines of the customer's stood in hermetically sealed rooms with almost no connection to the external environment. These customers did not permit the company even access to these machines. In some cases the customers would grant the measurement of performance data but required the data to be processed on their own site. As such the data was not permitted to be transferred outside the customer's plant. In yet other cases customers had limited access to internet which complicated the data transfer and limited the amount of data which could be transferred to the case company. Overall the development team faced a diverse set of customer segments with highly individual requirements and issues regarding the provision of the integrated solution. This led to high uncertainty due to the complexity and the insecurity about the overall attractiveness of the offering.

Also in Case E the customer landscape of the company comprised of a high variety of customer segments. While some customer segments were very knowledgeable about offerings and market conditions other segments were rather inexperienced. Moreover, all customers were highly diverse due to e.g. the market they operated in, the region they were located in, or the revenue structure they had. In one extreme case, the provision of this type of integrated solution became a license to operate in that specific country - without this provision no further machines could be sold. The diversity among the customers created uncertainty about the degree of customization of the integrated solution offering. In particular uncertainty arose around the balance of customization to fulfill the customer's needs, and standardization to create internal efficiency. In addition, as the customer segments were very diverse not all feedback collected from the sales department reflected a strong need for the offering. For those customer segments with positive feedback of the value proposition, uncertainty emerged about the level of risk covered in the contract. Here the team had to find the right balance because a too high risk level would expose the company to undesirable external volatility, while a too little risk level would be unattractive for the customers. Especially since some customers might already have used the low risk levels and alternative offerings in their business models. This uncertainty concerned with understanding the value for the customer was particularly challenging as the functional-oriented integrated solution implied many abstract concepts which were difficult for the team to express in monetary terms. As a result, the team experienced uncertainty about the benefit, specifically the monetary benefit, for the customer. Questions about the change in the customer's cash flow, financing schemes, access to equity financing and potential savings arose. The answer to these questions was characterized through high complexity due to the diverse customer landscape. Thus the value would result different for existing machines and new machines, for different customer segments, and vary potentially across different regions. The answer to these questions was seen as critical for the project success because it would enable the team to scope the integrated solution. Moreover, the identification of the customer's value would aid the team to subsequently determine the share of that value the company would earn, i.e. to price the integrated solution.

Examples from the Cases

Case A
Uncertainty around customer readiness and customer-specific restrictions regarding data protection.

Case E
Highly diverse customer segments led to uncertainty about the attractiveness and the benefit of the offering.

4.4.4 Country Specific Legal Settings

Legislations can affect the operation and the development of the integrated solution. In particular for globally operating players, like the participating companies in this benchmark, the local regulations were of high relevance for their offerings. These local legislations in general could enable, hamper, or even prohibit the provision of the integrated solution under the originally indented terms and conditions of the company. Thus uncertainty arose around the local regulations and their impact on the business model.

Uncertainty Specific for Integrated Solution Development

Country Specific Legal Settings
Uncertainty arose around the local regulations and their impact on the business model.

Case C was confident in navigating local legislations as they were also highly relevant for the company's core business. The machines of the case company constituted critical infrastructure and were as such, subject to increased legal restrictions. The provision of the integrated solution of this company implied a performance based contracting. Here the challenge arose in the possibilities for reacting to non-paying customers. Specifically, options for reaction were strongly limited due to the fact that the machines represented critical infrastructure and could not be just turned off. Here uncertainty arose in the development team around options for action to control the risk exposure of the company in each local setting.

In the course of the development the project of Case E, the team discovered that different countries had different legislations regarding the provision of the integrated solution under development. Specifically, the countries differed in their legal setting regarding the standard industrial classifications. For the company this implied the categorization as more than one industrial classification when operating on an international level. A change in the industrial classification had strong impacts and could potentially imply different reporting schemes, larger provisions or diverse financing methods. This created uncertainty about all the differing country specific legal settings in all market in which company operated. The leadership of the company decided to not offer the integrated solution if the industrial classification had to be changed. Accordingly the development team was challenged to re-scope the integrated solution in order to continue operating within the existing classification. This uncertainty presented a strong knock-on effect to the scoping of the offering. Moreover the uncertainty was particularly challenging to investigate because the of the high degree of abstraction of the functional-oriented offering. Consequently, the balance in scoping the offering was also particularly challenging.

Examples from the Cases

Case C
Uncertainty regarding local legislations as the product element of the integrated solution is considered critical infrastructure.
Case E
Uncertainty regarding differing legislations of the standard industrial classification.

4.4.5 Changing Legislations

The development of integrated solutions is typically characterized through a long period to execute the development. This is caused by the complexity of developing product and service elements in parallel. Accordingly these longer development periods are exposed to external changes which may also arise through changing legislations leading to uncertainty about the impact of changing legislations on the business model. In the context of the benchmark some companies perceived uncertainty about the impact of these legislations on the business model under development.

Uncertainty not Related to Integrated Solution Development

Changing Legislations
Uncertainty about the impact of changing legislations on the business model.

In Case A, the company started the development of an integrated solution which strongly relied on the ability to monitor real time process data from the customers. In the course of 2018 the EU data protection directive came into effect and had two major impacts on the development of this integrated solution. On the one hand the customers of the company increased their IT-security requirements. This implied that the case company would not have been able to offer the integrated solution if it would not meet these requirements. Due to the fact that these requirements were customer specific, the company was forced to adapt the integrated solution and its IT-security to each individual customer. On the other hand the EU data protection directive impacted the company internally. New capabilities were required for the correct handling of the data, i.e. collecting data, owning data, deleting data or storing data. As such, the company had to build up new capabilities internally to fulfill the EU data protection directive.

Examples from the Cases

Case A
Uncertainty about the impact of the EU data protection directive (spring 2018) on the business model of the integrated solution under development.

4.5 Resource Uncertainty

Resource uncertainty was defined as attracting and retaining the required resources. In the benchmark it occurred around data, project staffing, and preparations for the execution of the integrated solution.

4.5.1 Data

Technical performance data of the machines represented one source of resource uncertainty. As for most of the integrated solutions in this benchmark, data represented the basis for all further analysis. In particular, the development of the technical model and the accuracy of the forecasting based on the data. Accordingly, issues around the input data were critical to be resolved.

Uncertainty Specific for Integrated Solution Development

Data
This uncertainty arose from issues around data cleanliness, reliability and availability.

In Case F uncertainty about the input data arose from data cleanliness, reliability, and availability. Unforeseen external impacts on the machines to be analyzed created data cleanliness issues which needed to be resolved. Even though the team did not anticipate the specific external impact parameters, it did anticipate that previously unknown parameters would impact the data cleanliness and thus, the forecasting outcome. Moreover, uncertainty arose about the reliability of the input data. Specifically, if the data was provided through the customer, the team was unsure if it could trust the data for the forecasting purposes of the integrated solution. Projects at highly complex production sites may have included many additional and unforeseen parameters. These could influence the forecasting outcome leading to high roughness in the results and hence, a lack of trust in the data source. Lastly, the ability of forecasting in the context of the integrated solution depended also highly on the amount of data available. Uncertainty arose about how much data would be available during the operation. Since the integrated solution under development depended highly on customer data, uncertainty arose additionally around the access to this data, as the customer might not have wanted to share it. Moreover, in extreme cases like new machine sales, no historical production data would be available overall. Here the team would be exposed to very high uncertainty as the production site might have been characterized through many previously unknown parameters impacting the later performance.

Examples from the Cases

Case F
Uncertainty around data cleanliness, availability and reliability.

4.5.2 Project Staffing

Uncertainty around project staffing arose from attracting and retaining employees with the skill-set required for the development of integrated solutions. This implied uncertainty around the overall existence of the required skill-set in-house and led some companies to collaborate with external partners. Moreover, the uncertainty around the project staffing was reflected in staffing of employees on multiple projects and ad hoc disruptions through organizational change or the operational business.

Uncertainty not Related to Integrated Solution Development

Project Staffing 1/2
Uncertainty around project staffing non-specific for the development of integrated solutions arose from the dependency on line managers for resource allocation and the staffing on multiple projects in parallel.

Uncertainty Specific for Integrated Solution Development

Project Staffing 2/2
Uncertainty around project staffing arose from attracting and retaining employees with the skill-set required for the development of integrated solutions.

Overall in the benchmark uncertainty arose around the required skill-set for the development of integrated solutions. This uncertainty was three-fold and implied commercial, technical, as well as project management skills. Although Case E had strong commercial skills in the development team and represented a generally strong engineering company, the specialized technical skills for the specific integrated solution were a rare resource in the organization. The technical skills required in the course of the development project were risk modelling skills on one hand, as well as machine performance modelling and forecasting skills on the other hand. With respect to the risk modelling skills uncertainty arose around their overall existence within the organization. The uncertainty around the engineering skills regarding the machine performance modelling and forecasting arose mainly from the resource availability of the employees. Here the company had very strong engineering skills in-house which were able to develop robust models for the forecasting of the machine performance. The uncertainty arose from their attractions and retention on the project because these employees supported various projects in the company.

Moreover, the development of integrated solutions required senior and experienced project managers. In Case E the development process necessitated tailoring it to the individual commercial and technical requirements of the integrated solution. Here the initial and also the second project manager perceived uncertainty about which work streams of the development process to pursue, which parts to carve out, and potentially which additional parts to include in order to develop the integrated solution. In addition, the strong engineering background of the project managers created uncertainty about the definition, integration and execution of the commercial part of the integrated solution. Being familiar with purely technical developments, the commercial part of the integrated solution, as well as the interrelation of the commercial and technical part, were particularly challenging. This created uncertainty about the suitability of the present project management skills.

In addition to the special skill-set required for the development of integrated solutions Case E, like all other benchmark cases, had to balance uncertainty around the staffing on multiple projects, as well as the ad hoc demand of staff through operations. The first aspect of staffing uncertainty regarded the staffing of team members on multiple projects. The time besides the solution development project was dedicated to other competing internal projects at the company as well as daily operational and ad hoc tasks. This created uncertainty about the sufficiency of staffing for the steadily increasing workload as well as the availability of staff for ad hoc issues emerging in the course of the project. Furthermore, specifically the engineering resources with the modelling and forecasting as well as the risk modelling skills were subject to ad hoc demands from the operational business. These were either ongoing development projects or sales projects where their input was required to finalize the offer for the customer. Uncertainty regarding the distraction through competing projects arose from the timing of the distraction, the type of resources affected as well as the size of the knowledge gap remaining within the team.

Case F suffered strongly from resource uncertainty as a knock-on effect from organizational change. A major organizational change in form of a merger of two companies withdrew resources completely from the project or demanded they temporal attention. On the one hand, a data analyst initially staffed on the project was reassigned to another project. This created uncertainty about the possibility of replacement. Although this reassignment was not anticipated a new resources could be allocated fast. The delay of the work was a few weeks partially due to the on-boarding time needed. On the other hand, the major organizational change drew attention through the new task of reorganizing and aligning the novel organization. Processes and functions needed to be redefined and the portfolio merged. This organizational change created uncertainty within the team from a resource perspective as a major lay-off throughout both merged organizations and a hiring-freeze were the consequence. The team members did not know whether they would get replacement for lost colleagues. The hiring-freeze had a time consuming process of application for additional resources as a consequence.

In addition and partially motivated through the merger, other team members like the technical project manager and the project manager left the company. The technical project manager left in the early phases of the development project and was able to handover his work to the team properly before he left the company. The resignation of the technical project manager created uncertainty about the redistribution of the open tasks and the possibility of replacement. When the project manager left however, the team received a comparably small hand-over, sized for only two months of absence as he was on paternity leave before his resignation. Thus, only the most critical tasks were to be executed during the paternity leave by the other team members, the other tasks would wait until his return. As he did not return after the two months paternity leave, essential uncertainty arose about the overall project continuation with the few remaining resources available. The workload was too large for the already small team and the quality of the deliverable as well as the time line were at serious risk. In addition, the team members individually experienced insecurity about the possibility of loosing further colleagues. Caused by the comparably little hand-over from the project manager, the team struggled with identifying all continuing tasks. Here the question emerged if the remaining team had the capability and capacity to execute these tasks.

Lastly, Case F experienced resource uncertainty through the dependency of the project organization on the line managers in the operational part of the organization. This describes uncertainty arising from staffing approval. The project management organization in the company depended largely on the official approval of resources from the responsible line managers. The resources required for the project came from various areas within the organization (e.g. marketing, operations, sales) and thus, multiple approvals from line managers were needed. Uncertainty around the approval process arose from the competition of the project with the daily operational tasks of the employees. Moreover the question of accounting the working hours internally was central to the approval decision.

Examples from the Cases

Case E
Uncertainty arising from the existence and availability of the required skill-set for the development, as well as overall staffing availability.
Case F
Uncertainty around availability and retention of staff for the development project.

4.5.3 Preparations for Execution

The preparation for the execution of the integrated solution caused uncertainty in most cases regarding the differing skill-set required for the operational phase. Especially sales skills of integrated solutions differed from the traditional product sales, and service skills differed regarding the capabilities and availability of the staff to execute the integrated solution.

Uncertainty Specific for Integrated Solution Development

Preparations for Execution
Uncertainty emerging around the differing skill-set required for the operational phase.

Resource uncertainty regarding the execution of the integrated solution in Case B arose particularly around the availability of staff. As a knock-on effect of the environmental uncertainty, a particularly long downturn in the industry led to a very resource-tight organization. Accordingly, employees had to manage high daily workloads. In the course of the development project the company's development process required the team to define the responsible group of employees responsible for the operation of the integrated solution already at the gate where the business case would be approved. However, organizational changes and increasing work-load for the employees caused uncertainty in the development team about the actual availability of this group of engineers for the operational phase. In addition, the high degree of traveling of this group of engineers was doing in the context of their other operational tasks aggravated the possibility to properly train them and provide them with the preparation for the service execution they required. This caused strong resource uncertainty within the organization threatening the inability to execute the developed offering.

Case C noted a strong difference between the sales and the service staff for the integrated solution compared to the staff responsible for product or service sales. Sales staff needed to develop the capability to pro-actively approach the end-customers because they usually sold the machines through distributors. This required the sales staff to be able to establish a long-term relationship with the customer and thus, move from a transactional to relational sales capabilities. In addition, the sales staff was required to not only comprehend and sell the technical features of the machine, but argue now for the commercial benefit of the integrated solution. It shifted the focus from selling an CAPEX-item and its benefits, to an OPEX-item and its differing benefits. This also implied the capability of value-based selling. These strongly differing requirements regarding the skill-set of the sales staff caused strong resource uncertainty within the organization about their overall existence and sufficiency in-house.

Moreover, Case C perceived a similar uncertainty regarding the service staff. Also here, the service employees were required to answer potential inquiries about the commercial part of the offering. Also, the execution of the integrated solution demanded an initial performance audit of the machines in order to forecast their performance. This audit called for high technical expertise of the service staff. Resource uncertainty thus occurred within the organizational about the existence and availability of staff with the required skills in-house.

Examples from the Cases

Case B
Uncertainty around the availability of trained staff for the execution of the integrated solution.
Case C
Uncertainty regarding the different requirements to sales and service staff of integrated solutions (compared to product sales and service), as well as the availability of the corresponding trained staff.

4.6 Relational Uncertainty

Relational uncertainty refers to the inability to predict the partner's future behavior and level of cooperation offered. In the benchmark it occurred in form of contracting, and around the collaboration with external partners.

4.6.1 Contracting

Contracting represents a classical relational uncertainty. It is the aim to establish a formal relationship with a partner. In the course of the benchmark uncertainty arose regarding the precise terms and conditions to be included in the contract.

Uncertainty Specific for Integrated Solution Development

Contracting
Uncertainty arose regarding the precise terms and conditions to be included in the contract.

One example of the relational uncertainty arising from contracting was represented in Case C. Specifically, uncertainty arose about the degree of detail and the specific elements a contract of integrated solution was required to possess. The development team was challenged through the creation of a contract where the terms and conditions limited the risk exposure of the company to an acceptable degree. As this company provided machines which were considered critical infrastructure, the specific terms and conditions were closely regulated by local laws. This led to relational uncertainty about the possibilities of risk control and the terms and conditions the company was allowed to use in the contract. Lastly, the company experienced relational uncertainty in the aim of creating modular contracts. The team perceived strong uncertainty around the complexity of comprehending the risk profiles of all contract module combinations thus, regarding the precise phrasing of each module.

In Case D contracting caused relational uncertainty because the integrated solution aimed for a long contracting period. Accordingly, the terms and conditions were exposed to the uncertainty of a constantly changing environment over the upcoming decade. This caused uncertainty in the team about the precise phrasing of the contract as the contract had to enable both, flexibility to adapt to upcoming events, and rigidity to protect the interest of both parties. In addition, the team perceived uncertainty about the forecasts and their accuracy over the upcoming contracting period. Moreover, the contracting in the company was conducted differently according to different sites of the company. While one site aimed for a highly detailed and precise contract structure, another site created the phrasings rather loose to enable play in the contract interpretation and thus, adaptation to novel condition. This created relational uncertainty with respect to the customer as the formal relationship with the case company would differ from site to site.

Examples from the Cases

Case C
Uncertainty regarding the degree of detail, and the terms and conditions to limit the company's risk exposure.
Case D
Uncertainty about the precise terms and conditions for contracting over a long contracting period.

4.6.2 Collaboration Partners

Relational uncertainty is particularly present in the course of industrial collaborations. Hidden agendas, conflicts due to cultural misunderstandings, differing functions and processes across companies can easily lead to the unpredictability of the partners actions. In the course of the benchmark relational uncertainty was present during the collaboration with co-creation partners, as well as during the alignment with the value network to prepare the operational phase of the integrated solution.

Uncertainty Specific for Integrated Solution Development

Collaboration Partners
Uncertainty arose from the unpredictability of the partner's actions through hidden agendas, conflicts due to cultural misunderstandings, differing functions and processes across companies.

In Case D the preparation of the value network and the change in the relationship with the customers caused relational uncertainty. Although the company was highly customer oriented and enabled a high degree of customization of the integrated solution, changing customer demands and their high price sensitivity led to relational uncertainty. In particular, the customers represented one of the biggest competitors as they often chose to take over major parts of the value proposition offered in the integrated solution themselves. Here the negotiations with the customers caused relational uncertainty regarding the scope of supply and the price points as the customers were prepared to execute many tasks themselves.

In addition Case D perceived relational uncertainty in the long-term relationship with the suppliers which build the machines. In the value chain, the case company provided the intelligence of designing the machines and handed the information over to specific suppliers in order to build the machines. As a way of expanding their offering portfolio the suppliers had begun to also provide major parts of the after-sales market. Although the integrated solution comprised of a package of different offerings, the suppliers offered parts of the solution for a lower prices as they were located closer to the customer. This created relational uncertainty in the development of the integrated solution because the team had to balance the good relationship with the supplier for the production of the machines, and the competition with the supplier in the provision of the integrated solution.

The development project of the integrated solution of Case A represented a co-creation of five large international companies. Relational uncertainty was strongly present with respect to hidden agendas, conflict management, and uncertainty about the actual capabilities of the partner. One of the core companies of the collaboration provided major parts of the software programming required for the integrated solution. This company had a strong interest to enter in the joint development project in order to learn from the case company, and develop a generalized solution for the whole manufacturing industry. This intention was however only partially communicated at the project initiation and remained mainly in form of a hidden agenda. Accordingly, the company promised a long list of deliverables required from the case company and ended up delivering them only partially or incomplete. This created strong relational uncertainty in the case company regarding the degree of commitment of the collaboration company and the overall usefulness of the deliverable.

In addition, the company experienced relational uncertainty with another collaboration partner who contributed to the development through software elements and hardware. The provided hardware through this partner was faulty and the search of the cause delayed the project by one year because it was not directly identifiable that the hardware constituted the issue. Once identified however, the partner was not able to resolve the issue and the company decided to include another collaboration partner for the hardware delivery. This caused strong relational uncertainty because the case company had to balance the good relationship with the collaboration partner in the context of the software deliverable, with the exclusion of the partner from the project regarding the hardware.

Lastly, Case A also perceived relational uncertainty with a collaboration partner regarding the partner's engineering capabilities. The engagement of the collaboration partner had been a strategic decision because the partner had already previously delivered major IT-systems in-house. The motivation arose thus from the expectation that the novel developed software would be integrated easier into the existing IT landscape as they were both delivered from the same supplier. However, the novel software to be delivered in the context of the integrated solution represented an area where the collaboration partner had little to no previous knowledge and experience. Thus, relational uncertainty emerged around the actual capabilities of the collaboration partner and the pace in which the partner could learn the novel skills required fast.

Examples from the Cases

Case D
Uncertainty about the behavior of suppliers and customers evolving to become competitors.
Case A
Uncertainty arising from unpredictable behaviour and hidden agendas in the context of co-creation with five major companies.

4.7 Organizational Uncertainty

Organizational uncertainty is defined as organizational dynamism both within the project, as well as between the project and its various internal or external stakeholders. In the benchmark it occurred around various topics: risk averseness, service culture, service portfolio management, internal placement and alignment of the project, slow internal processes, organizational change, internationality and diversity of the companies, language, adaptation of the IT systems, pricing, functions and processes for the integrated solution execution, and the development process.

4.7.1 Risk Averseness

Due to the radicality of integrated solutions for companies on their transition towards servitization the development project can encounter strong opposition from the organization. The antagonists may come from diverse parts of the organization being not at all, partially, or even directly involved in the development project. The risk averseness was specifically observed in the functional-oriented integrated solutions due to the high degree of abstraction of the offering.

Uncertainty Specific for Integrated Solution Development

Risk Averseness
Uncertainty around the organizational support for a high-risk offering under development.

The development project of Case F encountered not only support from the organization but also critical counter voices. Employees were worried about the risk of the project and if the team was able to handle the risks appropriately. Specifically, employees worried about the ability to define and estimate the risk as well as handle the performance forecasting sufficiently. In addition, questions about the cost of failure and the customer demand were raised. Here a knock-on effect of the environmental uncertainty became visible. As the company had many diverse customer segments not all sales staff reported a customer demand for the product and thus criticized the need for the development project. Uncertainty in this context arose within the team regarding the overall project approval and the ability of project execution. The concern was, that without the support of the upper management the project could not be developed. In addition, without specifically the support of the sales organization, the sales department would not sell the integrated solution as much as needed. This would hamper the fast establishment of a portfolio and thus expose the company stronger to cash variations.

In Case E the development project caused highly polar reactions within the organization. On the one hand the team experienced strong support, especially from certain regional sales organizations and some parts of the organization even urged for speeding up the process to enable an earlier launch. On the other hand the development team experienced strong rejection of the project. These counter voices occurred mainly in parts of the organization which did not operate close to the markets where the need arose. Three main reasons for the rejection of the development of the integrated solution were the high risk profile of the offering, the organizational identity, and the potential change in the industrial classification (including its organizational impact). The risk-concerned part of the organization worried about the ability to define and estimate the risk, as well as to handle the performance forecasting sufficiently. In addition, questions about the cost of failure and the overall customer demand were raised. The part of the organization concerned with the company identity was concerned about the strategic fit of such an offering in the overall portfolio. This segment felt that as a traditional manufacturer the case company should keep operating with the core capabilities. The last part of the organization which was skeptical regarding the development project was concerned with the potential change in the industrial classification. Here core decision makers raised questions about the need for changing the industrial classification and all the implied organizational adaptations.

These diverse reactions of the company created uncertainty within the team as they had to balance all parts of the organization. This implied uncertainty about the appropriate depth of due diligence regarding the scoping of the offering and the planning of the project to handle the risks. Additionally, the team experienced uncertainty about the overall project continuation as the diversity of reactions to the offering was also represented in the reactions of the core decision makers.

Examples from the Cases

Case F
Uncertainty regarding the organizational resistance due to the high risk profile of the integrated solution.
Case E
Uncertainty around the organizational resistance due to the high risk profile of the integrated solution.

4.7.2 Service Culture

Uncertainty regarding the service culture arises from organizational resistance to the transition towards servitization. Moving along the axis of servitization exposes traditional manufacturers increasingly with intangible concepts, where in extreme cases the actual product becomes a byproduct of the offering, i.e. the basis for delivering the service. The benchmark confirmed that the transition for product-focused legacy corporations can cause strong organizational resistance.

Uncertainty Specific for Integrated Solution Development

Service Culture
Uncertainty regarding the service culture arising from organizational resistance to the transition towards servitization.

The development team of Case A perceived uncertainty around the service culture to support the development and prepare the execution of the integrated solution. Specifically, the development team had to communicate clearly the benefit of service provision - let alone integrated solutions. The focus of the company laid on machine sales and basic after sales services such as maintenance and spare part sales. Now, with the development of the integrated solution and the bundling of different service and product elements, the company had to be convinced of the added value. It also implied making the sales of integrated solutions more attractive to the internal sales staff and align the incentives for them to sell integrated solutions. This was critical because at the time being product-sales increased their personal bonus more. The resistance to change was high and the team perceived strong uncertainty about achieving the change in mindset towards a service oriented company.

Also Case C represented a manufacturer with a solid product-focused history. Internally the company referred to its own "immune system" when indicating organizational resistance to change with the aim to protect the core business. While some parts of the organization saw the need for the transition towards more servitized offerings, other parts of the organization opposed the thought strongly. This created uncertainty about the ability to achieve the change in mindset towards a more service-oriented organization. In addition, the internal resistance was reinforces through the premium quality of the sold products. Employees argued that service would not be needed to that extend for premium products such as the company provided. The uncertainty around the cultural change became particularly relevant when the team needed the support from the opposing parts of the organization in the course of the development project and the preparation for the execution.

Examples from the Cases

Case A
Uncertainty around the ability to establish a service culture within the organization.

Case C
Uncertainty about the ability to reach organizational acceptance of the service offering in a product-focused organization.

4.7.3 Service Portfolio Management

Uncertainty arising from the portfolio was related to the aspects of integrating the integrated solution within the existing product and service portfolio of the company. This was particularly relevant for the functional-oriented integrated solutions as they overlapped strongly with existing offerings due to their high level of abstraction. Here uncertainty arose around the number and type of existing offerings which would be partially or fully replaced by the integrated solution and as such, cannibalize the own market share.

Uncertainty Specific for Integrated Solution Development

Service Portfolio Management
Uncertainty related to the aspects of incorporating the integrated solution offering within the existing product and service portfolio of the company.

In Case F incorporating the integrated solution into the existing product portfolio described the challenge of overlapping with other offerings. Already from the pure portfolio view uncertainty arose about the degree of overlap with the existing portfolio. Moreover complexity increased because in the practical context, where other differing integrated solution contracts were already sold, all contracts were customized. Here uncertainty arose through the degree of overlap with all customer tailored integrated solution contracts currently under operation. Thus target customers and the attractiveness of the offering to individual customers were unclear.

In addition, the merger of the case company with another company in the course of the solution development has created strong turbulences throughout the project. One aspect was that the portfolios of both companies had to be aligned. This meant in the context of the solution development, that after the integrated solution would have been developed for the existing portfolio, the offer would be expanded to the portfolio of the new company. This created uncertainty about the size and type of portfolio the integrated solution would need to adapt to, as well as lack of knowledge about the new portfolio to be integrated. It also created high technical complexity as a very different data set would need to be assessed, and potentially require a different assessment process.

Examples from the Cases

Case F
Uncertainty about the overlap of the developed offering with the existing offering portfolio, as well as the alignment of two offering portfolios due to a merger.

4.7.4 Internal Placement and Alignment of the Project

The development of the integrated solution caused uncertainty within the organizations with respect to the placement of the project and the alignment with all organizational areas involved. In particular the uncertainty arose due to the high degree of involvement from many stakeholders across the whole organization and its novelty.

Uncertainty Specific for Integrated Solution Development

Internal Placement and Alignment of the Project
Uncertainty within the organizations with respect to the placement of the project and the alignment with all organizational areas involved.

Case D experienced strong alignment uncertainty between the sales department and the operational department. Lacking processes and a tendency to not work across the business units caused misalignments in the initial stages of the development process. Representing a knock-on effect of limited resources, the employees also had full schedules. Pairing the overworked employees with the lack of processes to align the two departments, commitment to the project occurred rather on an ad hoc basis - even though a high willingness to help the project characterized both departments. Accordingly, the team perceived uncertainty around the degree of alignment between the two department which partially resulted in differing contract interpretations, and conflicts of interest.

In Case E the structure of the company assigned each business unit its own Profit & Loss (P&L) and as such, did not enable co-financed projects across business units. As a result, the development of the integrated solution had to be financed by either the engineering business unit or the service business unit. Yet by nature of the offering, it included resources from both departments. This caused strong political conflicts within the case company between the business units about the governance of the project. In this context uncertainty emerged about the anchoring of the project, the ownership, the governance, the risk accountability and resulting, the costs of the development and the resource commitment to the project.

The integrated solution was to be sold together with the new machines and thus part of the area of responsibility of the engineering business unit. Yet, after the sales process the service business unit would take over the execution of the integrated solution and thus in the service area of responsibility. In addition, the integrated solution would benefit both business units. On the one side it would indirectly enhance new machine sales and on the other side it would increase the revenue gained through service. Yet none of the business units had developed a similar offering before and had no area within the business unit where to place the project because it affected multiple areas. This created strong conflicts between the two business units about the anchoring of the development project and its ownership.

Through the multiple facets and risk profile of the integrated solution the question developed itself further to the field of governance. In addition to the conflicts of anchoring and ownership the case company struggled to find a way how to govern the project. Specifically uncertainty was experienced about what kind of decision board to assign, which members to include in the steering committee and who should lead the project.

Beyond this uncertainty, the responsibility for carrying the risk of the offering had to be defined. The company experienced uncertainty about which of the business units would expose their P&L to the risks implied by the offering. Both business units had a stake in the project as the offering demanded resources and responsibility from both business units. Yet the size of the risk profile was not trivial and as such the placement of the risk exposure within the company also caused strong discussions.

In the end, the uncertainty experienced about the anchoring, ownership, governance and risk accountability were related to the question of resource commitment. The attention was laid on the resource discussion about the subject matter experts. As the integrated solution demanded expert engagement from both business units, the resolution of the uncertainty named before represented a mean to clarify the resource commitment of the business units. This was a particularly critical discussion as the development of the integrated solution required resources of high expertise and of high demand for the whole organization. The structure of the business units with their own P&L also pressured the heads of the business unit to consider carefully in which projects to invest because they did not only have to meet company KPI's, but also KPI's for their own business unit.

Examples from the Cases

Case D
Uncertainty about the internal alignment of the sales and operational department due to lacking processes.
Case E
Uncertainty about the anchoring of the project, the ownership, the governance and the risk accountability.

4.7.5 Slow Internal Processes

All cases of the benchmark were large corporations and had as such standardized processes for their daily operation. While fulfilling the call for organized procedures, these processes also implied a time delay compared to ad hoc responses of small start-ups. This time delay caused uncertainty in the development projects regarding the fulfillment of the process steps in the context of tight development schedules, as well as the amount of work implied to fulfill the process steps.

Uncertainty not Related to Integrated Solution Development

Slow Internal Processes
Uncertainty regarding the fulfillment of the process step in the context of tight development schedules, as well as the amount of work implied to fulfill the process step.

Although present in all cases, Case A was most prominently impacted by this uncertainty. In the context of the reorganization of the company functions and processes were redefined. As such, the IT department aimed for a more thorough structuring of the IT resource allocation to diverse projects. Through the creation of a process which implied the completion of five documents and presentation of these documents to three different boards, the IT department aimed to achieve more transparency over the aim and duration of the IT resource to be allocated. The development team strongly relied on IT resources because the integrated solution comprised to a high degree of software. The originally assigned three resources for the project were cut down to one resource in the course of the reorganization of the company. Now, the newly established process of the IT department aggravated the allocation of the IT resource to the project even more. This created strong uncertainty about the overall availability of the resource for the project, as well as the point in time from which on the resource could be engaged.

Examples from the Cases

Case A
Uncertainty regarding the availability of staff applied for through slow internal processes.

4.7.6 Organizational Change

Organizational change disrupted all companies from the benchmark. Due to the long development period required for integrated solutions as product and service have to be developed in parallel, the development projects are exposed to larger, and long-term changes within the organization. The type of organizational change varied from team reorganization, department reorganization, company reorganization, or even a merger. Commonly organizational change created high uncertainty in all areas of the company. This uncertainty had a strong tendency to knock-on to other uncertainty types such as resource uncertainty, relational uncertainty, or technical uncertainty. The uncertainty was multifold and varied from temporal disruption of relevant processes and functions, lack of resources or the required skills to fulfill a certain function, or simple stagnation.

Uncertainty not Related to Integrated Solution Development

Organizational Change
Uncertainty about the type and duration of disruptive programs in the organization and their knock-on effects.

Case F was exposed to the strongest organizational change - a merger. In the course of the development project the organization merged with another large company. This created strong turbulences throughout both organizations and a major lay-off. The remaining employees experienced a strong condensing of work and many additional merger-related tasks to fulfill. Moreover, the company decided on a hiring-freeze, hampering fast staff replacement. This created a highly volatile environment with constant changes in responsibility and structure. Accordingly high uncertainty around this disruption emerged. Regarding the solution development project this uncertainty targeted specifically the availability of resources. Discontinuation of team members in the company and distraction of team members from the project represented the main uncertainty. In combination with a long application process for resources, this led to a substantial uncertainty about the overall project continuation.

Also Case A was subject to organizational change. Here the whole company reorganized with the aim of company-wide standardization and alignment. Equally in this case, a major lay-off was the consequence of the reorganization and employees with high experience left. The reorganization had a major impact on the development project as all team members were required to focus on the implementation of the company-wide program. Some team members were even re-assigned and no longer staffed on the project. This created major uncertainty about the remaining knowledge in the team, the pending tasks to be completed, as well as their priority. In addition, central contact persons which were consulted in the course of the project left the company, and staff originally planned to join the team in the further course of the development was not available any longer. This created uncertainty about the availability of the required knowledge within the company and the potential for replacement of the missing staff. In addition, the reorganization implied a travelling-freeze. In the development of the integrated solution this hampered the collaboration with another subsidiary in southern Europe which had close contact to a pilot customer. Hence the team coordinated the whole collaboration remotely under strong uncertainty regarding the mutual comprehension.

Examples from the Cases

Case F
Uncertainty about the project impact of an organizational merger.
Case A
Uncertainty about the project impact of a company-wide reorganization.

4.7.7 Internationality/Diversity of the Company

High internationality of the company and the development team caused uncertainty regarding the complexity of the project coordination. Cooperation across cultures, borders, languages, and time zones increased the complicatedness of communication and fast problem solving. In addition, rather de-centralized companies perceived increased uncertainty when developing a generalized integrated solution due to the high degree of decision power of the individual subsidiaries.

Uncertainty not Related to Integrated Solution Development

Internationality/Diversity of the Company
Uncertainty regarding the complexity of the project coordination implying cooperation across cultures, borders, languages, and time zones.

In Case D the offering was developed in an international team across borders. Exemplary, the team had to engage strongly with the headquarter regarding the spare part pricing. Due to a lack on an mediating agent the two parties, the development team and the team in the headquarter, and a travelling freeze for internal travels, the development team was exposed uncertainty caused by the internationality of the company. As a consequence misunderstandings, conflicts caused by varying values in the different cultures, differing process lengths, and contracting terms, as well as variability in the spare part pricing arose. Moreover, the company structure enabled a high degree of freedom for the hubs. As such, the hubs decided on their own spare part prices and navigated their own operations with a high degree of freedom. This caused a knock-on uncertainty for the development team with regards to the volatile pricing of the integrated solution, as well as the changing availability of the service technicians, which had to be defined in the contract of the integrated solution.

Case B also represented a highly international company. In this case the development team was spread out across the globe and four different time zones. Here uncertainty arose through the high degree of complicatedness arising from the coordination of the project. Moreover, core employees of the development project were also strongly engaged in operational tasks which implied a large extend of travelling activities. These travelling activities could lead the employees to remote place with limited possibility of external communication. This led to high uncertainty regarding the possibility of advancing the development project and aligning all relevant team members with each other.

Examples from the Cases

Case D
Uncertainty arising from the international coordination of the development project.
Case B
Uncertainty due to the high degree of complicatedness of international project-coordination, and availability of internationally travelling staff.

4.7.8 Language

Communication represents a central part of development activities. The alignment of sender and receiver is key to success for the project but also subject to uncertainty. In the benchmark native and vernacular language differences caused strong communication issues.

Uncertainty not Related to Integrated Solution Development

Language
Uncertainty arising from native or vernacular language differences.

Case B is a prominent example of native language issues. As elaborated before, the team was highly international and executed the development project across four time zones. Accordingly the team language was set to be English. This required all non-native English speakers to adapt their communication to the abilities of the English language. It also required all native English speakers to adapt their speaking clarity and content to the language abilities of the counterpart. Moreover, some of the team members which contributed crucial parts of the technical development were not able to speak English beyond the communication of basic concepts in the beginning of the project. They learned English in the course of the project. All these elements led to strong uncertainty regarding the mutual comprehension of the team members and thus, the alignment and progress of the project.

In Case A the uncertainty around language arose from vernacular misunderstandings. Case A collaborated with four other partners from differing industries. This implied a differing jargon for each industry and company. The case company, representing a solid manufacturer, had to communicate with a partner from the software industry. Here uncertainty arose due to vernacular language misunderstandings as certain word had differing meanings in each context. This was particularly relevant during the phase of the requirement definition for the deliverables of all collaboration partners, as well as during conflict management.

Examples from the Cases

Case B
Uncertainty arising from native language challenges.
Case A
Uncertainty arising from vernacular language challenges.

4.7.9 Adaptation of the IT Systems

Organizational uncertainty regarding the adaptation of the IT system arose in the benchmark through the alignment of the execution process and the virtual twin of the process in the underlying IT-infrastructure. This uncertainty was caused through a high level of detail and thus, a high degree of complexity in the alignment of both processes.

Uncertainty Specific for Integrated Solution Development

Adaptation of IT Systems
Uncertainty caused by a high level of detail and a high degree of complexity in the alignment of both, the virtual and the real process.

Case C represents a prominent example. Operating in a legacy organization of transactional sales, the IT-systems for accounting and invoicing were optimized to one-time payments. The provision of the integrated solution implied however a constant follow up on many small cash-ins over the contracting period of several years. It also implied continuous issuing of invoices. This created uncertainty about the degree of rework required on the existing IT-infrastructure regarding the automatization of the process. Another example from Case C was the automatized creation of contracts through their online portal. Offering the customer the possibility to hand-pick elements of the portfolio to create their own, tailored integrated solution via the online-portal required a strong change in the underlying IT-infrastructure. Also here uncertainty arose around the degree of adaptation of the IT-system needed to automatize these processes.

Examples from the Cases

Case C
Uncertainty around the adaptation of the existing IT infrastructure to enable the management of continuous invoicing and small-scale cash-in.

4.7.10 Pricing

Understanding the financial effect on the business model and defining a suitable price for the offering represents one of the hardest challenges for traditional manufacturers. Especially more servitized offerings call for a value-based pricing approach, forcing manufacturers to determine the monetary value of the abstract offering. Once the value is determined, additional uncertainty can arise around finding the right balance to set a price which is profitable and yet, competitive.

Uncertainty Specific for Integrated Solution Development

Pricing
uncertainty arising from finding the right balance to set a price which is profitable and yet competitive.

In Case D the pricing of the offering represented a major challenge. The spare parts were sourced from different entities within the organization and thus, differing price lists circulated within the company. Aiming for a precise cost estimation, the team perceived uncertainty about actuality of the prices they were working with. This manifested itself in novel spare parts without a price, old spare parts which had been replaced in the system by newer ones which also not yet had a price, or old spare parts where the price had changed. Moreover, the hourly rates for the service technicians executing the integrated solution changed over time and varied across regions. This strongly increased the complexity of the pricing. On top of that, the team faced a general price increase and was challenged to match the scope of supply with the price, while still staying competitive. Considering the long contracting period of the integrated solution the development team faced challenges in estimating the costs and defining a profitable as well as competitive price for the integrated solution.

In Case F modelling the financial side of the offering was challenging for the team. Specifically, uncertainty arose from calculating the expected cash flow, establishing the overall accounting process, and determining the amount of provision necessary for the offering. In the cash flow calculation uncertainty arose due to the high complexity of the task. As the company had many production sites which were highly diverse with distinct service offerings, the definition of the calculation and underlying accounting process implied complex comprehension of the company business and the accounting discipline. In addition, the sufficient granularity in the accounting process had to be defined, to keep a balance between sufficient transparency and efficiency. Considering the internationality of the case company the modelling of the global portfolio implied a high degree of complexity. In connection the establishment of internal accounting rules of how to handle the offering in the accounting process made the commercial modelling highly complicated.

In the context of sizing the provision needed for the integrated solution, the concept of financial risk pooling across production sites was investigated. Uncertainty arose in this context as risk pooling would have eased financing the integrated solution internally through lower provisions. Yet, it was unclear under which specific conditions companies were legally allowed to risk pool.

Based on understanding the internal cash-flow, the value-based pricing of the integrated solution represented a central part of the development process. It would assure the margin to be gained and determine the competitiveness of the offering. Uncertainty in the context of pricing arose from forecasting the occurring costs and determining a price point that would enable both profit and competitiveness. The team experienced uncertainty about the actual value of de-risking for the customer and the payment terms desired.

Examples from the Cases

Case D
Uncertainty around volatile spare part prices.

Case F
Uncertainty arising from the financial modelling of the financial impact of the offering, sizing of provisions, the ability to risk pool and value based pricing.

4.7.11 Functions and Processes for Integrated Solution Execution

The execution of the integrated solution requires the definition of underlying functions and processes, as well as their alignment within the existing organizational structure. Here uncertainty arose in the benchmark regarding the identification of specific functions and detailed elements of all main and supporting processes.

Uncertainty Specific for Integrated Solution Development

Functions and Processes for Integrated Solution Execution
Here uncertainty regarding the identification of specific functions and detailed elements of all main and supporting processes.

An example from Case A implied the creation of a 2nd-level support. Here the tasks of the 2nd level support had to be defined and resources allocated. Complexity arose through assuring the customer 24h-service and accordingly, establishing this 2nd-level support across several time zones. Additional challenges arose for the development team through the identification of all business areas which would be involved during the execution of the integrated solution. Here the newly defined processes had to be aligned with the existing processes of the business areas throughout the whole supply chain.

This created uncertainty through the high level of detail and the complexity of coordinating the large stakeholder network.

In Case B the uncertainty around the functions and processes represented a knock-on effect of the high degree of internationality of the company. Operating globally the individual subsidiaries had a high degree of decision freedom and were partially already providing parts of the integrated solution to local customers. This created uncertainty about the knowledge existent in all sites of the company regarding the execution of the integrated solution. In addition, the development team evaluated to allocate the processing of the data required for the forecasting in one specific low-cost country where the company had already many IT-resources. Yet, another South American site had already initiated to develop and provide parts of the service to customers and possessed thus, a high level of expertise. This created uncertainty within the team regarding the location for the execution of the global integrated solution.

Examples from the Cases

Case A
Uncertainty arising from the high level of detail required for the definitions of 2nd level support functions and processes for the execution of the integrated solution.
Case B
Uncertainty around the coordination of the international establishment of functions and processes for the execution of the integrated solution.

4.7.12 Development Process

Most development processes of the case companies were optimized for the development of their machines. Accordingly, the technical part of the integrated solution was to be executed very thoroughly and with a high degree of precision. Yet, the commercial part of the integrated solution was the poor cousin of the technical part and did not nearly receive as much attention. Rather it was often underestimated and lacked detail and alignment with the technical part. Often this caused high uncertainty after the project had been approved and the actual development began. Here uncertainty emerged about the actual process of the commercial development, or the alignment with the physical product caused strong challenges.

Uncertainty Specific for Integrated Solution Development

Development Process
Uncertainty in the project team about the precise process required for integrated solution development.

Case D was located on one extreme of the uncertainty arising from the development structures. The company had not yet defined a precise development process for integrated solutions and was thus lacking a basic underlying process. No solid procedures were defined and no binding roles with corresponding responsibilities were assigned in the project. While applying a strong process for making an offer to the customer during operations, the underlying development had to date not been defined. On the one hand, this forced the team members to work under highly flexible conditions. On the other hand, the team worked in a constant "fire-fighting"-mode as it had to respond to high degrees of uncertainty, which were partially caused by the lack of processes. This uncertainty manifested itself in miscommunication, lack of taking responsibility, or simply a longer time to market.

Case E was very representative of other cases in the benchmark regarding infringements experienced due to the development process. This case was located at the other extreme of the infringements caused by the development process. The process itself was optimized to structure the development of the machines from the company in a lean way. A side effect of the optimization for machine development was that additional requirements or tasks for other types of development were extinguished. Therefore core processes and tasks to answer the characteristics of integrated solutions, services, or purely digital offerings were not provided. In the case of the development of the integrated solution, especially the commercial part, and the mutual impact between the technical and commercial part, caused high degrees of uncertainty and knock-on effects.

In previous developments of integrated solutions or offerings with an intangible aspect, the company's development process was tailored according to the needs of the project. This relied strongly on the experience of the project manager and the team. Here a knock-on effect from the resource uncertainty was clearly present because both project managers drove the project focused to the main extend on the technical development of the tools, and less on the commercial development. Thus they were neglecting the large commercial aspect required for the development of an integrated solution. Additionally the integrated solution the case company was developing implied a very high degree of radicality, which was not given by previous offerings. This highly radical project caused infringements in the stage gate process due to the high degree of flexibility in responding to novel conditions it required. Lastly, as the development process did not consider the commercial aspect to the degree required for the development of integrated solutions, it did equally not consider the alignment of both parts. In the present development of the integrated solution this caused strong infringements because the technical aspect lacked maturity. As such, answers needed from the commercial team could not be given by the technical team due to the immaturity of the technical model. The project would have strongly benefited from a technical pre-development and a corresponding alignment of both elements.

These aspects led to very high uncertainty in the development project. On the one hand, the process created uncertainty in the project team as many process steps were expendable or too detailed for the development of an integrated solution. This was felt especially in the technical tools-development. On the other hand, central requirements were not included or considered central to solution development. Here especially the commercial development was neglected as well as its alignment with the technical development. This setting created high uncertainty for the development team around the actual development process for integrated solutions. Specifically, the team was unsure how to navigate the commercial development and its alignment with the technical development.

Examples from the Cases

Case D
Uncertainty arising from lacking internal processes for the development of the offering.
Case E
Uncertainty of developing an integrated solution in a product-focused development process.

4.8 Summary

Summing up, the benchmark results show that the development of integrated solutions is non-trivial due to the high degree of uncertainty implied. In the context of the benchmark all uncertainty types were present in all cases. From all uncertainty types the organizational uncertainty type contained the most instances of uncertainty. Strong instances here were the change of the organizational culture towards a service mindset, and the disruption of all cases through organizational change. Furthermore, the companies struggled most with the development of the commercial part of the offering. Specifically the pricing, contracting, and modelling and forecasting of risk profiles caused strong uncertainty which called for new skills within the organization. Lastly, often uncertainty had knock-on effects causing additional uncertainty in other areas. This highlights the importance of the systemic view on uncertainty management in the context of integrated solution development.

5 Best Practices and Conclusion

This section gives suggestions for the companies based on insights gained from literature and best practices from the benchmark. It elaborates recommendations for each uncertainty type and then ends with a conclusion about the overall challenges of integrated solution development.

5.1 Best Practices

The following sub-sections give specific recommendations for the uncertainty encountered in the solution development. The recommendations base on empirical insights gained from best practices in the benchmark, as well as insights gained from academic literature. Each recommendation is summarized briefly in the beginning of the sub-section of each uncertainty type and then elaborated in detail below. A summary of the recommendations can be seen in table 2 below.

Uncertainty Type	Recommendation
Technical Uncertainty	Pre-Piloting or Early Piloting Strong Investment in Project Planning and Scoping Phase
Environmental Uncertainty	Co-creation with the Customer
Resource Uncertainty	Building Network Capabilities Internal Capabilities Staffing
Relational Uncertainty	Contracting Data Sharing
Organizational Uncertainty	Agile Management Practices Organizational Learning Plan Adjustment of the Development Process Preparation for Execution Stakeholder Management Project Execution Strategic Support

Table 2: Summary of the recommendations for the individual case

5.1.1 Technical Uncertainty

Pre-Piloting or Early Piloting

Recommendations

Pre-Piloting or Early Piloting
Pre-piloting specifically the technical feasibility through a very rough version with one customer (or historical data) enables to spot technical uncertainty before the actual development. Although the main impact of piloting concerns the technical uncertainty, it also benefits the early identification and reduction of other uncertainty. In response, the team can plan management practices for the uncertainty reduction accordingly. If no pre-piloting is done (or feasible), early piloting of the integrated solution with continuous improvement and refinement also aids identifying and reducing uncertainty early in the process.

The application of pilots in the development of integrated solutions has shown high success rates in the benchmark. Companies applying a pre-pilot created a very rough first version of the integrated solution and tested it with a customer. This was especially relevant for the testing of integrated solutions for which no historical machine performance data was available. Alternatively, companies benchmarked themselves in a pre-study against historical data of their machine performance.

The testing of the integrated solution in form of a pre-pilot, i.e. before the actual development, helped strongly to decrease uncertainty. Especially strong reduction of uncertainty was observed in the technical uncertainty type. Here pre-piloting helped the teams to identify early specific engineering related challenges like modelling and forecasting of the machine performance, as well as issues arising from data comprehension and quality of the data to be used. In addition, the close collaboration with the customer enabled the company to reduce uncertainty about the scoping of the integrated solution because instant feedback from the customer was received.

Pre-piloting showed also positive impacts on all the other uncertainty types. Thus, in the case of pre-piloting with a customer, relational uncertainty was identified and reduced early in the process. Companies were able to e.g. identify specific contractual clauses necessary for the control of the company's risk exposure. Furthermore, environmental uncertainty was reduced - especially in the context of pre-piloting at a customers site. The company was able to decrease uncertainty about the customers value and increase the customers readiness for the offering. Companies were also able to reduce resource uncertainty because they were able to better determine the type of resource needed for the development process. This was particularly relevant for specialized skills needed for the project. In extreme cases, companies were able to engage with external partners to source these skills. Lastly, pre-piloting enabled the companies to reduce organizational uncertainty - especially organizational uncertainty arising from the organizational resistance to the project. As such, the pre-pilot helped to familiarize the company with the type of integrated solution to be developed, and mature the organization around the thought of the offering. Through the successful execution and the collected learnings of the pre-pilot, the development team was able to present a success story of the project and decrease many concerns of the organization.

Overall, the pre-pilot exposed the development team early to the most apparent issues in the development, enabling them thus a longer time for reaction and problem solving. It was also easier for the organization to approve a pre-pilot because the overall costs and the risk profile of the pre-pilot were smaller compared to the full-scale development project.

If no pre-pilot was conducted, uncertainty was also partially reduced through early piloting. This referred to development projects, which launched a pilot early in the development process and iteratively kept improving through the gained learnings. On the one hand, this enabled the testing of a more advanced version of the integrated solution compared to the version tested in the pre-pilot because some development had already been done beforehand. On the other hand, it delayed the identification and reduction of uncertainty compared to the context of pre-piloting.

Strong Investment in the Project Planning and Scoping Phase

Recommendations

Strong Investment in the Project Planning and Scoping Phase
Stronger investment in the project planning and scoping phase enables the team to familiarize itself with all aspects of the complex offering. Potentially a technological pre-development or a commercial pre-study is required to reduce uncertainty around the scoping and determine the subsequent development steps. It also aids the team to work towards the purpose of the development despite the emerging uncertainty and find alternative solutions.

Radical projects, especially radical projects of high complexity, require strong front-loaded investments in their development. Integrated solutions represent radical projects as they typically disrupt their markets and demand highly different skills from the organization to develop them. As a result from their radicality, integrated solutions are characterized through high degrees of uncertainty in their development. Managing the uncertainty of integrated solutions often results in high complexity in the technical, the commercial part of the offering, or the interrelation between the two.

Due to the high degrees of uncertainty, it is critical for the development team to understand the requirements of the integrated solutions in detail. This implies the requirements from the customer's perspective in form of the technical and commercial scoping of the offering, but also the organizational requirements regarding e.g. the development process and the skills needed to develop and deliver the offering. Based on this, the development of integrated solutions calls for a thorough due diligence in the beginning of the project to understand it's implications for the organization and the customers. Accordingly, the team has to familiarize itself thoroughly with the offering and all its complex facets the project planning and scoping stage.

The strong initial investment also aids the team to fully understand the technical and commercial scope, and thus the purpose or goal of the development. In the case of development projects with high uncertainty, like the development of integrated solutions, this helps the team to keep the focus on the purpose or goal. This is particularly relevant because high uncertainty will challenge the project throughout the development and no linear "stage gate"-like development is possible. Enabling the focus clearly on the goal of the project facilitates the team to find alternative solutions which also achieve the goal, despite the high uncertainty. Accordingly the corporate structures have to align with the needs of radical innovations such as the development of a integrated solution and enable stronger investment in the project planning, scoping and potentially pre-development phase.

Potentially, after the idea for the offering has been identified, the need of a technological pre-development or a commercial pre-study can emerge. The technological pre-development may determine the overall feasibility or shape a crucial part of the offering needed to fully describe the business case. The commercial pre-study may provide critical answers regarding the market requirements, the definition of the underlying business model, or other highly influential factors framing the offering legally or financially. Both pre-activities can help to strongly reduce uncertainty in the following development and have shown successful results in the benchmark. Based on the outcome of the pre-studies, the technical and the commercial development steps can be derived.

5.1.2 Environmental Uncertainty

Co-Creation with the Customer

Recommendations

Co-Creation with the Customer
Co-creating integrated solutions with a strategically chosen core customer helps to reduce uncertainty about i.a. the value for the customer of the integrated solution, the scoping of the value proposition, and it's impact on the customer's business model.

The co-creation of the integrated solution with the customer may be strongly considered. As integrated solutions comprise of a highly tailored service component and it's development is mostly novel to traditional manufacturers, the collaboration with the customer can be highly beneficial for reducing uncertainty in the development. The customer should be strategically chosen to represent the customer segment for which the integrated solution is developed. In particular co-creation can reduce uncertainty around i.a. the scoping of the integrated solution, the value for the customer, the impact of the integrated solution on the customer's business model, requirements setting and contracting. Moreover the created relationship with the customer enables the possibility of piloting and confidence for early sales. Additionally, technical uncertainty and the actual feasibility can be tested.

5.1.3 Resource Uncertainty

Building Network Capabilities

Recommendations

Building Network Capabilities
Pursuing a strategy of engaging collaboration partners in the development of integrated solutions enables the company to access expert knowledge external to the company and speed up the development. The engaged experts can also analyze the technical and commercial progress, and provide critical feedback.

Acknowledging the challenge of sourcing all required specialized skills for the development of integrated solutions in-house, a strong external network has shown high relevance in the benchmark. As such partners may selectively be chosen with the specific core competences needed to contribute to the development. Moreover, the company is able to speed up the development process as the required knowledge can be accessed faster. The collaboration with a partner can also provide critical reflections on the development project, technically or commercially, and thus point the development team towards not yet addresses issues. In the benchmark, this has shown high success rates especially in the context of the technical development of the integrated solution. The collaboration partner scrutinized the modelling and forecasting of the case company critically and helped the development team to reveal additional critical technical uncertainty.

However, the establishment of such a network requires time before the initiation of the development project. Accordingly, it is key to have the mandate from the upper management to develop the company, and as such the company's own capabilities as well as the network, in the strategic direction of the integrated solution. In general, external knowledge may be sourced from various origins like e.g. suppliers, consultancies, universities, research institutes, open source platforms etc. The strategic support and creation of an external network enables the initiated project to draw upon the capabilities required once the project is initiated.

Internal Capabilities

Recommendations

Internal Capabilities
The development of integrated solutions requires a high degree of expert involvement. The required expertise originates from both, subject matter expertise and seniority in the organization. The subject matter expertise comprises of technical, commercial and project management expertise.

The development of integrated solutions often challenges developing manufacturers through the high amount of specialists required for their development. Developing not only the external network towards the development of the integrated solution, but also the internal capabilities has shown as being highly beneficial in the benchmark.

Successful projects in the benchmark had a high degree of experienced and senior employees staffed on the project. This targeted on one hand seniority in their specific area of subject matter. The high degree of subject matter expertise aided the teams to avoid, or quickly resolve, subject matter uncertainty. This targeted specifically project management skills for large project, technical skills, and commercial skills. This way the team could focus on the holistic development progress and the novel uncertainty caused through the unique features of the integrated solution. On the other hand the high degree of experience also referred to the seniority within the company. Here expertise arose through familiarization with the corporate structures, processes, and a large intra-organizational network.

The manufacturing companies in the benchmark were quite strong in the identification of the subject matter experts, which needed to be engaged for the technical development. Yet, the identification of the precise commercial and project management skills challenged the companies. Examples of specialized skills required in the commercial part of the solution are e.g. strong capabilities in the area of contracting, financial modelling and risk assessment/ forecasting. Strong contracting capabilities would enable the organization to develop a modular contract to facilitate customization while controlling the risk profile of each individually customized contract. Moreover, the ability for financial modelling regarding i.a. the internal cash flow calculation and amortization time for each project, the definition of the internal accounting processes and the ability to comprehend the complexity of financial cash flow portfolio needs to be considered. Furthermore, the risk modelling and forecasting for the commercial part of the integrated solution requires strong statistical skills. The company should strengthen the capabilities in comprehending the total risk exposure of each contract as well as the portfolio risk modelling. In the context of project management skills expertise with agile project management, as well as very strong stakeholder management capabilities are key.

Based on both insights, a thorough definition of the type of expertise required for the development project is key. Strong stakeholder management to attract and retain these experts in the development project supports the development.

Staffing

Recommendations

Staffing
A generous estimation of project staffing can counterbalance an increase in workload and complexity further in the development. Due to the high uncertainty this additional workload can be anticipated. Aiming for a staffing >80% of the key team members on the project enables full focus on the development project and less vulnerability to ad hoc issues in competing tasks.

More generous project staffing in form of the total number of staff on the project, as well as a staffing of at least 80% of each individual employee has shown the advantage of team members being able to fully focus on the project. Staff represents a constant deficiency in project management. Too small teams can lead to long delays of the lead time or complete stagnation of the project progress. In addition, employees get distracted from their project work through other operational or ad hoc tasks. If thus employees are staffed for only 20% of their time, through further distractions their actual dedication may decrease to only a few hours on an ad hoc level per week. In these few hours reserved for the development project additional time can be deducted through the need of the employee to mentally reengage into the pending tasks. Moreover, in the case of lacking resources, the organization would need to approve additional resources afterwards. Besides the uncertainty about the availability and approval of the additional resources, the process of application is usually lengthy and administrative.

In the case of the development of integrated solutions a lack of staff in some part of the development project may be expected. First, these projects are commonly longer development projects. This long time span exposes the project to high uncertainty occurring along the progress. Second, due to the high uncertainty implied by integrated solutions the complexity and workload will naturally increase in the course of the development.

The recommendation to encounter these challenges comprises of a more generous initial estimation around project staffing. This recommendation is two-fold: higher staffing in form of the total number of employees working on the team (ideally 5-9), and a high percentage of the employees time dedication on the project. A suitable total number of 5-9 team members will be able to proceed fastly with all areas of the project, while keeping the number of communication channels comparably low. In addition, a high percentage of the employees time staffed on the project enables the employee to continue working on the project despite ad hoc distractions. The benchmark has shown that a project staffing of >80% was highly beneficial. This way projects may be sped up because employees can stay focused on one task for a longer period of time and work more efficiently. The employee will also need less time to pick up the task again in case of a distraction. Lastly, through a generous initial project staffing the lengthy approval process afterwards (in case of lacking employees) and the uncertainty about the organizational approval of additional resources can be avoided.

5.1.4 Relational Uncertainty

Contracting

Recommendations

Contracting
Strengthening the contracting capabilities of the company to create customized contracts efficiently while being able to control the risk profile of each contract individually is strongly recommended.

Developing strong contracting capabilities early in the development process has the advantage of optimizing the final physical outcome of the commercial part of the integrated solution. Thus early focus can be paid to modularization and the assessment of risk profiles.

The contract of the integrated solution serves to establish the formal relationship between the provider and the customer. As integrated solutions are often highly tailored offerings and the contract represents the tangible version of the offering, the creation of the contract is key to their success. Here the step towards contract modularization can be evaluated to enable customization. Special attention should be paid to the individual risk profiles resulting from each customized contract. Based on the risk profiles certain uncertainty factors may be in- or excluded from the coverage.

Yet, as no contract can cover and foresee all possible scenarios in the source of the contract life-time all contracts show "grey areas". These grey areas are scenarios which are either not, only partially, or vaguely covered in the contract. Strong contracting capabilities and experience with contracting of integrated solutions can help to cover most of them in the contract. Nonetheless, a good relationship with the customer, specifically for integrated solutions, is central in the context of the grey contract areas.

Data Sharing

Recommendations

Data Sharing
Loosening the company data sharing regulations to enable external sourcing of knowledge.

Data sharing is an important concern for collaborations with external partners such as e.g. universities, suppliers, consultancies or customers. Accordingly, too strong data protection rules hamper the knowledge exchange with the external collaborators and thus the overall success and depth of the collaboration. In one case, strong data protection regulations from the organization hampered and prohibited external collaboration. The recommendation of data sharing stresses in this point the openness of the company, while the above recommendation of external collaboration encourages to engage stronger into external collaborations.

5.1.5 Organizational Uncertainty

Agile Management Practices

Recommendations

Agile Management Practices
The application of agile management practices has shown positive results in the context of high uncertainty. Broadening its application beyond the purely engineering development to the whole project execution may aid coping with non-technical uncertainty. Specifically, characteristics like the small team size, co-location, full staffing of team members, creation of fast and iterative deliverables to receive early feedback and a high degree of customer engagement are crucial. The application of agile comprises of both, the agile mindset and the use of agile methodologies.

Due to the high degree of novel uncertainty the companies developing these integrated solutions are exposed to, they struggle with traditional stage gate project management approaches. The benchmark has shown that the application of agile management practices had very positive effects on the management of the uncertainty and thus, the development process of the integrated solutions.

The positive effect of agile management practices resulted mainly from the following characteristics of agile: short feedback loops, co-location of the small team, a high percentage of staffing on the project, clear prioritization, central documentation, visualization of progress tracking, and a high degree of customer engagement. The creation of short feedback loops and thus fast small deliverables enable the team to achieve a steep learning curve and detect uncertainty early in the process.

A co-located team paired with a high percentage of staffing on the project enable the team to detect and solve uncertainty fast. The co-location helps the team to avoid obstacles through delayed or misunderstood remote communication and few, direct communication channels. Thus, a faster and easier problem solving can be achieved. In addition the high percentage of staffing, the concept of agile enables full dedication and focus on the project. Thus, no distraction through other side projects hampers the project progress.

The organization of agile projects implies a clear prioritization of the workload, central documentation and the use of visualization tools for progress tracking. The concept of breaking the work down into work packages and prioritizing these packages gives the team clear guidance in their work progression. Once one work package is finished, the corresponding team member has a clear overview of his or her subsequent task. The central storage of all project related documents facilitates all team members to find the documentation fastly and on-board new team members. Moreover the application of visualization tools for the project progress, such as a Kanban board or a burn-down chart, proved highly useful. Here all work packages still remaining in the backlog, under progress and finished, can be tracked for each individual team member as well as for the overall project. Lastly, the close collaboration with the customer gives the team fast feedback on the project and assures close alignment with the customer's needs.

Nonetheless it should be stated that the transition towards agile management practices does not only imply the application of a method like Scrum, but a corporate culture of agile. As such, concepts like personal empowerment, responsibility, freedom and flexibility are key to success. The practices derived from agile in the benchmark were strongly supported from the teams which had the agile mindset.

Organizational Learning Plan

Recommendations

Organizational Learning Plan
Projects with high uncertainty require a very different project management approach than projects with low uncertainty. For these projects academic literature has proposed e.g. the application of an organizational learning plan. This learning plan reduces uncertainty in the progress of the project through fast iterations of uncertainty identification, creation of assumptions about the uncertainty, testing the assumptions and evaluating the result of the test. Key here is the evaluation based on the individual uncertainty, but also it's knock-on effect on other uncertainty types and the overall project progress.

The application of the organizational learning plan has the advantage of enabling the company to deal with the varying uncertainty throughout the development process. Projects with varying degree of uncertainty require different project management approaches. As shown beforehand, the development of integrated solutions exposed companies to strong and novel types of uncertainty. While projects or tasks of low uncertainty may be managed with an operating plan and stage gate models, project of high uncertainty require much shorter planning horizons and fast iterations. Besides the proposed agile approach, a complementing method proposed in literature to manage strong project uncertainty is the application of an "organizational learning plan" (Rice et al., 2008).

In an organizational learning plan, all dimensions of uncertainty are mapped and iteratively reduced to an acceptable level of uncertainty (or even eliminated). The process comprises of a learning loop and the evaluation of the learning. In the course of the learning loop, all uncertainty for each uncertainty type (technical, environmental, resource, relational and organizational in the case of integrated solutions) are defined. Subsequently their level of criticality (low, medium, high) is evaluated and assumptions about the uncertainty made. Based on the assumptions, alternative approaches for testing the assumptions are identified and the most suitable method chosen. For this method, measurement criteria for proving or disproving the uncertainty assumption are defined as well as the test of the assumptions conducted for the most critical uncertainty (Rice et al., 2008).

After this learning loop, the learning is evaluated. The results are analyzed regarding the content learned and the effect on the assumptions made. It is specifically evaluated if it was possible to prove the assumption and thus, reduce the uncertainty. If it was not possible to prove the assumption new assumptions, should be defined and the learning loop repeated. In addition, the effect of the learning on the other uncertainty types as well as on the overall project progress should be evaluated. Finally, the new learning loop may be defined (Rice et al., 2008). A template for the organizational learning plan taken from the paper can be seen in the appendix II.

Adjustment of the Development Process

Recommendations

Adjustment of the Development Process

The introduction of Technology Readiness Levels in the development of integrated solutions aims at lowering the uncertainty exposure. A slight offset of the technical and commercial development of the integrated solution, and thus pre-maturing the technological or commercial part, can avoid knock-on effects in the further development. It moreover reduces the aggregated uncertainty exposure to the team in each development phase. In addition, the adjustment of the traditional development process to the commercial requirements of the integrated solution is needed. As such the commercial development process has to be defined and the relevant departments (e.g. legal and finance) included.

For the development of integrated solutions a different approach to the development process may be considered. Here, two aspects are central: (1) The integration of technology readiness in the development process, and (2) the adjustment of existing product development process to specifically the commercial part of the integrated solution.

(1) Technology Readiness Assessment

Level	Description
1	Principle research into the core properties of a technology.
2	"Invention" of a concept or application for the technology. Shift from principle to applied research.
3	Initial "proof of concept" of critical functionality through active R&D (Analytical and laboratory studies in appropriate context to validate previous analytical predictions).
4	Low-fidelity validation in laboratory environment. Technological advancement now focused on meeting project requirements.
5	Validation of basic technological elements in a relevant environment. Test "set-up" to be of higher fidelity than at TRL 4.
6	High-fidelity "alpha" prototype demonstrated in a relevant environment.
7	"Beta" prototype (of appropriate or full-scale) demonstrated in an operational environment.
8	Completed component, sub-system or system qualified to relevant project requirements and/or regulatory standards.
9	Certified component, sub-system or system proven to meet all project requirements through "real world" operation.

Table 3: Technology Readiness Levels (Mankins, 1995)

The separation of technology and product development has proved highly relevant in the context of integrated solution development. As the commercial development of the integrated solution often bases on the technology development of the solution, a technology readiness assessment of the technological part can be recommended. This approach is already widely used in purely technical development. If the technology, e.g. a software tool, does not possess the required maturity, a technology development should precede the actual development of the integrated solution.

The most commonly applied technology readiness levels were developed by NASA (Mankins, 1995) and distinguish nine different categories. These categories are summarized in the table 3.

The application of technology readiness levels implies two benefits. First, knock-on effects of drastically changing technological features leading to changing commercial features can be avoided (or reduced). This prevents large amounts of rework of the commercial part of the offering. In addition, the team is exposed to high uncertainty implied by the development of integrated solutions rather in sequence - not on an accumulated level. First, a technological pre-development or a commercial study takes place. Second, the actual development of the integrated solution is initiated. This implies an overall lower uncertainty exposure in each phase of the development, because their accumulation is restricted.

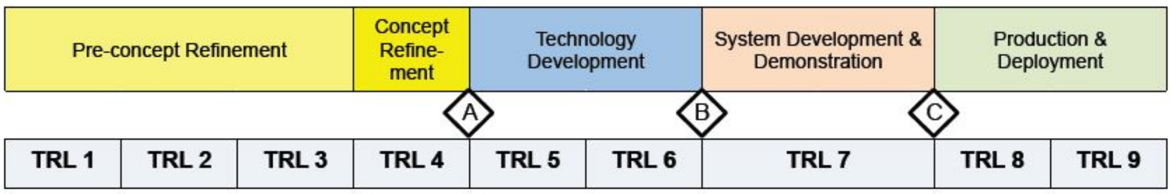

Figure 5: Technology Readiness Levels in the development process

The degree of technology readiness matures throughout the development process. Figure 5 shows an example of a development process and its alignment with the technology readiness levels from The Department of Defense in the United States of America (Olechowski et al., 2015). Milestones A, B, and C mark finished process steps.

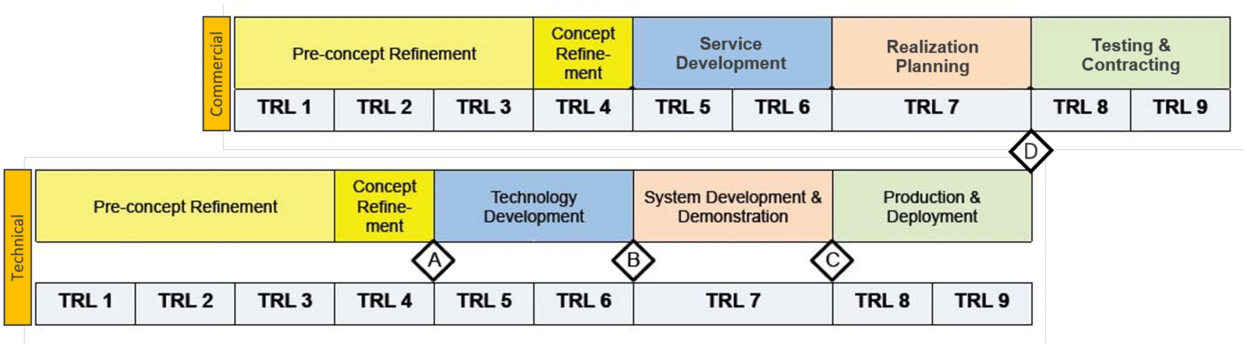

Figure 6: Exemplary Technology Readiness Levels in the development process of integrated solutions

The application of technical and commercial development according to the technology readiness levels is highly individual. The degree of overlap, or initiation of the commercial development may vary depending on the individual project characteristics of the integrated solution. If the technology has a very low level of readiness, sequential technical and commercial development may be considered. In case the technology has a higher level of technological readiness, a stronger degree of overlap may take place. Lastly, if the technology and the commercial development possess roughly the same technology readiness, parallel development may be considered. This distinction should be elaborated in each individual case. An example of a possible development process overlap for the solution development can be seen in figure 6.

(2) Adjustment of the Existing Development Process

In addition to the introduction of technology readiness levels the adaptation of the development process tailored for product development to the characteristics of the integrated solutions should be considered. As for the purely technological part of the integrated solution, the traditional features of the existing process may be kept. Yet, the novel characteristics of the integrated solution, given through the commercial part call for adjustment.

A commonly used model in literature from Aurich (2006) proposes a parallel development of what he calls "product" and "technical service". The model may be seen in figure 7. Here, the commercial aspects of the service are developed in parallel to the technical product development. Aurich describes that in each step several iterations between product and service development take place to align them both (Aurich et al., 2006).

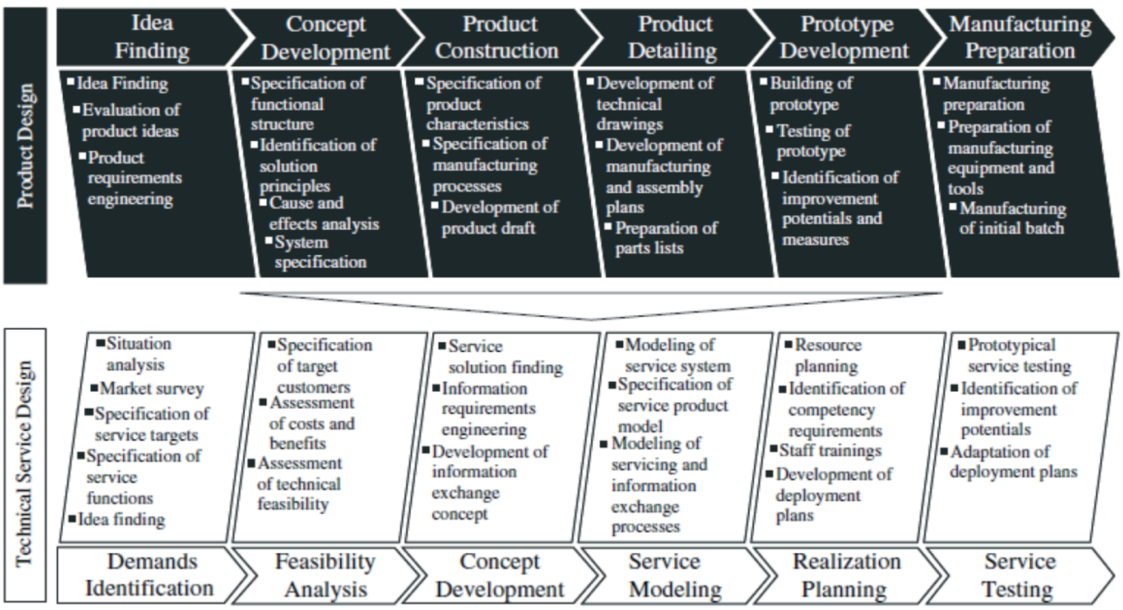

Figure 7: Development process of integrated solutions (Aurich et al., 2006)

Based on the conclusion from the technology readiness levels, a technical pre-development or commercial pre-study may cause slight offset of the two processes. Moreover, special attention should be paid to the requirements of the commercial development. Here, different departments need to be included, diverse competencies required, and distinct tasks performed. Resulting from the empirical observation in the benchmark, specifically the legal and the finance departments need to be engaged early. These departments may not only give input to the overall scoping of the integrated solution, but also to the "worst case scenario" and general risk profile. This input is highly central to the stakeholder communication.

Based on the previously described development process from Aurich, the commercial tasks to be performed need to be defined for the individual development case. As such, the overall development process should give guidance for the developing team, but each team has to tailor the development process for integrated solutions to their special case.

Preparation for Execution

Recommendations

Preparation for Execution
Aligning the organizational structure and processes for the new type of offering enables a smooth execution. Special attention should also be paid to achieve organizational support. Specifically the sales and service staff should be trained, the whole supply chain of the delivery of the integrated solution designed, and novel support functions created (as far as necessary).

Integrated solutions require a different approach to their execution than what traditional engineering companies have established. Their commercial part implies a high degree of individual customer contact and service, and calls for different structures and processes which enable this operation.

The company has to consider the whole supply chain over the entire life cycle of the integrated solution, from the initial sales contact to the end of the contract period, and potentially even to a renewed contract or extended contract period. This perspective implies long-term planning and the establishment of functions and processes accordingly. These new processes may require a shift in the sales approach, because sales of integrated solutions are less transactional and rather relational. In addition, not only the direct processes need to be defined, but also supporting processes like e.g. 2nd level support and the back-office. Here, the split of responsibility of the e.g. back-office of the integrated solution as well as the other offerings which its supports, have to be clearly defined.

Moreover, specifically in the initial phase of the execution, thorough training of sales and service employees is essential. Due to the novelty of the offering, employees are inexperienced in the execution of this offering and may even show potential resistance. Therefore their support and training is key to success. Potentially the training sessions and initial execution of the offering require support from the project team. Here a thorough hand-over to the executing organization facilitates the process of engaging sales and service.

In addition, thorough resource planning and provision for the execution is needed. As the execution of integrated solutions is resource intensive and requires a different approach than traditional sales, the attraction of capable employees is central. Potentially, the company needs to hire sales and service resources only for the execution of the integrated solution if the required competence profile cannot be found in-house.

Stakeholder Management

Recommendations

Stakeholder Management
The large stakeholder network if team developing integrated solutions calls for a strong management approach. The distinction between approvers, responsibles, supporters, consultants, and observers can help the team to apply suitable management practices. Special attention should be paid to the management of the approvers as they have a high influence over the project continuation.

The most successful project in the course of the benchmark was characterized through very strong stakeholder management. Since the development of integrated solutions comprises of a larger stakeholder network, internal and external to the company, a thorough communication plan is key to success. This enables the team to manage the expectations of all stakeholders and gather their input to the development.

Five general stakeholder categories can be distinguished for the development of integrated solutions: approvers, responsibles, supporters, consultants, and observers. Approvers are stakeholders who have both significant power and influence over the development project. Their support is highly critical to the development project. Responsibles are mostly comprised of the team members. These stakeholders are responsible for the project delivery and have strong influence over the quality. Supporters are stakeholders who make a strong contribution to the project in an assistant role, being staffed only for a small fraction of their time on the development project. Consultants are stakeholders with high expertise who give input to the project in the course of the development on an ad hoc basis. Lastly, observers cover all other stakeholders who have an interest in the status and the outcome of the project. They are not making an active contribution.

Management strategies for these stakeholder groups can reach from one-to-one stakeholder meetings, steering committee participation, weekly and monthly updates, newsletters etc. For companies on the transition towards servitization the stakeholder management is specifically key, because often the development teams encounter a high corporate resistance to the project. Broadcasting the project and its purpose on a continuous basis has proven highly beneficial in the benchmark. This also implies to keep close contact to the supporting and critical voices in the organization as both can shape and strengthen the offering. In the context of upcoming decision meeting close stakeholder management of core decision makers is central to the outcome of the meeting. To ease the workload of stakeholder management each core team member can be responsible for managing the support of his/her manager (and the manager's manager).

Project Execution

Recommendations

Project Execution
The project execution should enable flexibility in the reaction. In case the uncertainty causes too high workload and complexities in the project, change requests for more staffing resources and additional time should be made.

Throughout the development of integrated solutions high uncertainty will challenge the planned execution. The adaptation of the project to this constantly changing context requires from the team fast adaptation of work packages, processes and the ability to re-prioritize. It also implies an understanding of the workload and the capabilities of the team members. In this context the use of change requests to the initial project plan is highly useful if the project is not executed with agile management practices. The change requests refer often to an adjustment of the time or resource plan. The flexibility in the project execution also implies spontaneous changes if core elements like e.g. the absence of a core decision maker in a decision meeting emerge.

Strategic Support

Recommendations

Strategic Support
Strategic support of the development of integrated solutions is highly beneficial. It enables the team freedom to operate through higher resource provision. In addition, an organizational maturation process is initiated, preparing the company for the execution and weakening the counter voices. It also reduces the extend of political discussions about project anchoring and governance.

The development of integrated solutions in the context of the benchmark without the official strategic mandate has proven highly difficult. The root causes are multifold. First, the support of the solution development through the executives and upper management liberates automatically more freedom to operate for the development team. Through the strategic mandate core resources like subject matter experts and a higher budget are granted. Second, strategic focus on the development of the integrated solution enables the whole organization to prepare for the project. Accordingly, processes and functions are aligned easier and the company matures around the thought of the solution provision. Third, strategic support weakens the doubt of the organization and thus the opponents of the solution development. Basing the development project on the overall strategic decision for the project, the team experiences less obstacles and corporate resistance towards the project. Fourth, large corporate discussions about the governance and anchoring of the project are easier solved because the strategic mandate creates the motivation to solve these political discussions fast to progress with the actual development.

5.2 Conclusion

This report provides detailed insights into the uncertainty faced by manufacturers when developing integrated solutions. To provide these insights, this report describes the results of a benchmark study undertaken in the Nordic manufacturing industry. Six development cases of integrated solutions are compared and contrasted regarding the uncertainty encountered, the criticality and latency of the uncertainty, and the uncertainty management practices applied. The uncertainty was analyzed within five mutually exclusive and collectively exhaustive types: Technical, environmental, resource, relational and organizational uncertainty. This benchmark offers several key learnings about uncertainty in the development of integrated solutions.

First, it was observed that all five uncertainty types challenged the progress of the solution development in the companies. Although to a varying degree and depending on the characteristics of the specific integrated solution developed, all companies experienced uncertainty in all types. Common uncertainty could be identified and best practice management practices derived.

Second, the organizational uncertainty type represented in all cases the most challenging type. Specifically the development of the integrated solution within existing structures and processes mainly tailored for pure hard- and software development posed challenges to the companies. In addition, each company experienced major internal reorganizations. This created in all cases knock-on effects particularly impacting the availability of core resources in the development. Moreover the creation of a service culture within the company, and thus an understanding of the value and importance of integrated solutions, challenged all projects through organizational resistance during the development.

Third, the specific characteristics of integrated solutions like e.g. long life-cycle, large stakeholder involvement and high complexity, created high and novel uncertainty in each uncertainty type. The parallel development of a technical product and a service component, created high complexity in the development process. Moreover, the intangible service component posed novel uncertainty to the development teams and the organizations as both were optimized and organically grown around pure product development.

Fourth, uncertainty created knock-on effects and caused additional uncertainty, mostly in other uncertainty types. In particular, the uncertainty types created knock-on effects onto the organizational uncertainty type, or the organizational uncertainty type created a knock-on effect on the other uncertainty types. As such, changes in the environment of the development project, challenges in the relational or technical dimension as well as resource uncertainty often called for differing organizational processes, structures or regulations. In addition, organizational changes, structures, processes, regulations or the culture created knock-on effects in the other uncertainty types. This observations calls for a strong alignment of the organization with the development of integrated solutions. Furthermore, it calls for staying particularly alert to the knock-on effect of uncertainty types on the organizational aspect.

Summarizing the development of integrated solutions confronts organizations on their transition towards service with a novel uncertainty. The development context of high uncertainty is imperative for a differing project management approach and suggests the introduction of strong stakeholder management and agile management practices.

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Appendix

I Questionnaire

Personal experience:

1. Role:
2. Experience in company (in years):
3. Experience in role outside and inside the company (in years):

Integrated solution of the company:

4. Can you explain the concept of your integrated solution?

Development Process:

5. Can you summarize for me the major steps of your development process for the integrated solution? (Vasantha et al., 2012)?

6. What went especially well during the development project of the integrated solution? Why?

7. What went especially not so well during the development project of the integrated solution? Why? How did you manage it? How strong was the impact? How predictable/anticipated was it to happen?

7.1. **Environmental challenges**

7.1.1. Customers, competitors, pricing, revenue model, demand changes, changes in legislation, competitor's actions, technological development, political developments...

7.2. **Technical challenges**

7.2.1. Product, Service, System integration

7.3. **Resource challenges**

7.3.1. Capabilities, Information, Financing, Interdependencies of Projects, macroeconomic resources (energy, cost of licensing, raw materials)

7.4. **Organizational challenges**

7.4.1. Intersection with functions or processes, internal stakeholders (e.g. acceptance of "service-culture", risk aversion of decision makers, varying uncertainty perception, strategic ambiguity in the prioritization of the project...), project planning + execution (e.g. goal definition, determination of methods, design of experiments (simulation of lifecycle), alignment of sub-projects, forecasting...)

7.5. **Relational challenges**

7.5.1. Which stakeholders?

7.5.2. Relationship: formal/informal, split of costs and risks, Intellectual property, Quality and timing of agreed delivery, availability and reliability, hidden agendas, commitment, actual capabilities, management of uncertainty, bankruptcy...

Additional information:

8. In retrospective: What should have been done differently and how? (lessons learned)
9. Is there anything else you would like to add or clarify?
10. Could you point out any additional information that would support my research project?
11. May I contact you again?

II Organizational Learning Plan Template

The table 8 below shows the template for the Organizational Learning Plan. As this template was not created specifically for the development of integrated solutions the uncertainty should comprise of five categories: Technical, environmental, organizational, resource and relational. The corresponding definitions of the uncertainty as well as examples may be found in the second chapter.

Learning Plan Process	Uncertainties			
	Technical	Market	Organizational	Resource
Conduct Learning Loop				
1. Define what is known and what is unknown in each category.				
2. Assess level of criticality (High, Medium, Low).				
3. Develop assumptions for each uncertainty.				
4. Identify, explore and assess potential alternative approaches to testing each assumption.				
5. Select alternative testing approaches deemed most efficient in terms of learning per dollar spent per time.				
6. Establish measurement criteria for proving or disproving the assumptions.				
7. Define tasks and timetable for each test.				
8. Conduct the tests.				
Evaluate Learning				
9. Post-test, analyze and assess what has been learned. (For example, can an assumption be converted into a fact, or have we disproved the assumption? If the latter, what is our new assumption about the uncertainty?)				
10. Explore how the learning impacts assumptions about uncertainties in other categories (T, M, O, R).				
11. Determine how the learning affects overall project progress.				
12. Define next steps required for subsequent iterations.				
Proceed with next learning loop				

Figure 8: Organizational Learning Plan according to (Rice et al., 2008)

Contact Details

If you would like to have further information about this project or engage in upcoming uncertainty management research in the solution development context please contact:

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